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## Introduction

Water temperature is a key aspect of water quality in a stream environment. Stream temperature is determined by a combination of factors including solar radiation, air temperature, riparian vegetation cover, ground water, stream discharge, channel shape, orientation and climate.

On the Santa Fe National Forest (SFNF) stream temperature is managed for the success of cold water fisheries. Cold water fish species include salmonids and non-game species such as longnose dace, fathead minnow, Rio Grande chub and Rio Grande suckers. Among the salmonids present on the SFNF (non-native rainbow, brown, brook and cutthroat trout), the only native is Rio Grande cutthroat trout (see Photo 1). Rio Grande cutthroat trout (RGCT) are listed on the Regional Forester's Sensitive species list in Region 3. SFNF stream temperature standards have been designed to optimize the life history of this fish.

**Photo 1.** Rio Grande cutthroat trout.

RGCT growth, health and reproduction are all affected by water temperature. Typically, as water temperature increases, so does fish performance. Although fish exhibit increased performance with temperature, there is also a lethal temperature threshold. No lethal temperature information is currently available for RGCT, so information has been related from other dry climate inland cutthroat trout species like the Lahontan cutthroat trout (*Oncorhynchus clarki henshawi)*. The Lahontan cutthroat trout had a 100% survival rate at 75.2 F (24°C), but declined to 35% at 78.8 F (26°C). Mortality was 100% within 48 hours at 82.4 F (28°C). The upper limit for growth and long-term survival is somewhere between 71.6 (22°C) and 73.4 F (23°C) (Dunham 1999). These temperature limits were based on optimal conditions with high food availability and good water quality, not taking into account the other stressors that may exist in stream environments. It is possible that the actual lethal limits are lower due to water chemistry and other environmental factors.

Cutthroat trout reproduction is also affected by temperature. Smith et. al (1983) compared egg quality of cutthroat trout in a variety of water temperatures. Eggs in cold water were expelled easily and were in good condition. In warm water the eggs were expelled with difficulty, were cloudy or opaque and often broken. Eggs spawned from two-year-old adults exhibited 74% viability in the coldwater while in warm water only 6.9%.

RGCT survival is affected not only by daily maximum temperatures but also daily temperature fluctuation (diurnal difference). Under natural conditions stream temperatures can fluctuate up to 36°F (20°C). It is thought that dramatic changes in temperature put stress on the fish living in the system. Several studies conducted on Lahontan cutthroat trout support this assumption. Dickerson and Vineyard (1999) found that juvenile cutthroat subjected to fluctuation temperatures from 68-78.8°F (20-26°C) grew, but not as much as juveniles held at a constant

temperature of 68°F (20°C). Meeuwig et al (2004) found that juveniles experiencing fluctuation temperatures from 53.6- 75.2°F (12-24°C) also grew less than juveniles held at lower constant temperatures. These studies do not set up threshold fluctuation levels for a decline in the fitness of cutthroat trout, but do demonstrate that diurnal difference can affect the growth and success of these fish and thus should be considered in a temperature management plan.

The maintenance of cool stream temperatures necessary for the success of a coldwater fishery depends on many factors. Protection from excessive solar radiation is one of the most important. A healthy riparian zone provides stream shade that blocks solar radiation (see Photo 2). Healthy stream systems also frequently have deep undercut banks that protect the stream surface from solar radiation. Historic management practices on the SFNF have led to a decline in riparian health. Cattle browsing on riparian vegetation and collapsing the fragile undercut banks have exposed more stream surface to solar radiation. Brown out areas where riverside vegetation has been removed by dispersed often unmanaged recreational uses (including fishing, camping, and ATV use) also exposes more of the stream to the sun. Typically, a degraded stream system will display increased maximum daily stream temperatures as well as high daily temperature fluctuation.

**Photo 2.** A healthy riparian zone found in Reach 12 on the Pecos River (28-Aug-02).

Stream temperature is also affected by elevation. In a healthy system as elevation decreases stream temperatures generally increase. It has been believed that RGCT are rarely found below 5500 feet due to this natural phenomenon (Hatch *et. al*, 1998).

## Materials and Methods

Stream temperatures were measured for each stream over a minimum of three months. Temperatures were recorded at least 6 times a day using a StowAway Tidbit thermograph (Onset Computer Corporation, Pocasset, Massachusetts; see Photo 3). Ideally, thermographs were placed in the stream by June 1$^{st}$ and were removed after September 30$^{th}$ of the same year. The tidbits were placed in sections of stream deep enough not to expose them to air during summer low flows. They were anchored to the stream bottom using rocks or rebar. Sites were selected to assist in native fisheries management as well as to further locate sources of thermal influence.

Temperature data collected from thermographs was analyzed for seven thermal characteristics. A seven-day average of maximum stream temperatures was calculated for each day between

June 1st and September 30th. The seven day averages were then compared to SFNF water temperature standards. A three-day average of maximum stream temperatures was calculated for each day between June 1st and September 30th. The three day averages were then compared to New Mexico Environmental Department (NMED) water temperature standards. Daily temperature fluctuations for each thermograph were calculated for at least a consecutive three month period. Diurnal difference was calculated by subtracting the minimum recorded daily temperature from the maximum. Monthly maximum, minimum and average temperatures were calculated for at least a consecutive three month period at each thermograph site. Finally maximum temperatures across all thermograph sites on one stream on one day were compared.


**Photo 3.** StowAway Tidbit used to measure stream temperatures on the SFNF.

Many different standards for evaluating stream temperatures have been developed. This study utilizes two standards one adapted from NMED and another adapted and modified by the SFNF from standards developed by US Fish and Wildlife Service and NOAA Fisheries for native salmonids (see Table 1). Both standards look at temperature data collected between June 1st and September 30th.

NMED stream temperature standards are based on a 1999 analysis derived from the Clean Water Act and Total Maximum Daily Loads mandate for water quality standards (NMED 2000). NMED analysis of stream temperature for a high quality, cold water fisheries (HQCWF) is based on two factors. First, temperature cannot exceed 23°C (73.4°F) for more than an hour during deployment. If it does the stream is considered not supporting of a HQCWF. The second factor looks at stream temperature across time. Based on the number of hours a day that the stream exceeds 20°C (68°F) it is labeled as not supporting, partial supporting or full supporting (NMED 2000).

In our analysis of the NMED standard, if temperatures were met or exceeded across three consecutive days (on average instead of one time) then the stream was at risk (68-73.3°F) or not properly functioning (≥73.4°F). This simplification of the NMED protocol was necessary to adapt the protocol to existing forms of temperature collection on the SFNF. Future temperature collection efforts on the SFNF will follow the NMED protocol and standards more rigorously.

NMED's standards are based on known thermal limitations of non-native introduced trout species which evolved under different climatic and geographic conditions (rainbow trout, German brown trout, and eastern brook trout). In order to facilitate successful recovery on native RGCT the SFNF standards took a more conservative approach that looks at long term effects on cutthroat trout.

SFNF standards use seven-day average maximum temperatures. Standards based on a seven day period are more stringent and more in line with approaches taken by U.S. Fish and Wildlife Service and NOAA Fisheries across the western United States (Oregon Department of Environmental Quality 1997 and EPA 2003). The lower temperatures were also an approach by US Fish and Wildlife Service and NOAA Fisheries when adequate life history information for the species was not available. The 64/70 standard is the generic standard for western native salmonids (ODEQ 1997). These two factors (seven-day average, lower temperatures) allow the SFNF to be more pro-active in improving watershed conditions for native fish as well as improving impairments to water quality before a stream is listed as impaired on the 303(d) list.

**Table 1.** SFNF and NMED water quality temperature standards.

| Water Temperature Standards | Properly Functioning | At Risk | Not Properly Functioning |
|---|---|---|---|
| **SFNF 7-day Average Maximum** | ≤ 64 °F | 64 to 70 °F | > 70 °F |
| **NMED 3-day Average Maximum** | ≤ 68 °F | 68 to < 73.4 °F | ≥ 73.4 °F |

## Results

Over the last three years, 47 thermograph stations have monitored 238.6 miles of stream forest wide. A total of 21 streams were monitored (see Table 2). Analysis of temperature data by SFNF standards has found 12 thermograph stations **properly functioning**, 20 stations **at risk** and 15 stations **not properly functioning**. Analysis of temperature data by NMED standards designates 23 thermograph stations as **properly functioning**, 12 stations as **at risk**, and 12 stations as **not properly functioning**. According to SFNF standards, seven streams are **properly functioning** for their whole monitored length: Beaver Creek, Cave Creek, Gallinas River, Horsethief Creek, Rito Café, Rito Perro and Panchuela Creek. By NMED standards, 11 streams were **properly functioning** for their entire monitored length: Rito Perro, Rito Café, Panchuela Creek, Rio Mora, Horsethief Creek, Hollinger Creek, Gallinas River, El Porvenir Creek, Chihuahueños Creek, Cave Creek and Beaver Creek.

**Table 2**. Forest-wide evaluation of stream temperature.

| Temperature Standards | Properly Functioning | | At Risk | Not Properly Functioning |
|---|---|---|---|---|
| **SFNF water temperature standards** | 12 stations ( 41.8 miles) | Beaver Creek, Cave Creek, Gallinas River, Horsethief Creek, Rito Café, Rito Perro, Panchuela Creek | 20 stations (100.7 miles) | 15 stations (96.1 miles) |
| **NMED water temperature standards** | 23 stations (107.3 miles) | Beaver Creek, Cave Creek, Chihuahueños Creek, El Porvenir Creek, Gallinas River, Hollinger Creek, Horsethief Creek, Rio Mora, Panchuela Creek, Rito Café, Rito Perro | 12 stations (51.1 miles) | 12 stations (80.2 miles) |

## Recommendations

By SFNF standards 96.1 miles of stream on the Forest are **not properly functioning** and another 100.7 miles are **at risk** for stream temperature. Management practices affecting these stream miles need to be examined to find a way to mitigate conditions.

The health of the riparian zone plays a key role in temperature reduction. A healthy riparian zone often provides dense stream cover and limits the amount of solar radiation hitting the

stream. In many areas on SFNF the riparian zone has been degraded by grazing pressures, intense human recreation use, road encroachment and other factors. These areas should be rehabilitated to help decrease stream temperatures. Implementation methods include:

1. Augment current riparian area density by planting native species.
2. Grazing practices should be managed to protect the riparian area. Riparian grazing should be eliminated or highly reduced during the vegetation's growing season. Exclosure fencing or a rotational system across several pastures could also help relieve some pressure on the riparian.
3. Reduce number and limit the use of dispersed trails and campsites within the riparian zone.
4. Reduce number of roads and ORV trails in riparian zone. Decommission user-created stream crossings.

Stream widening due to collapsed banks and erosion also increases stream temperature by exposing more of the stream to solar radiation. Returning the stream to more natural conditions would help reduce temperature. Implementation methods include:

1. Re-introduce large woody debris (LWD) into the stream and floodplain. LWD in the stream increases habitat complexity by creating deeper riffle and pool habitat. This will provide areas for water to collect and cool in the summer as well as providing over-wintering habitat. Any LWD project would utilize the best available science for LWD implementation to avoid previous stream improvement mistakes.

This report is the first attempt at analyzing stream temperatures on the SFNF. At this point we are still collecting baseline data for our systems. An expansion of this program would provide additional information necessary for managers to make educated decisions:

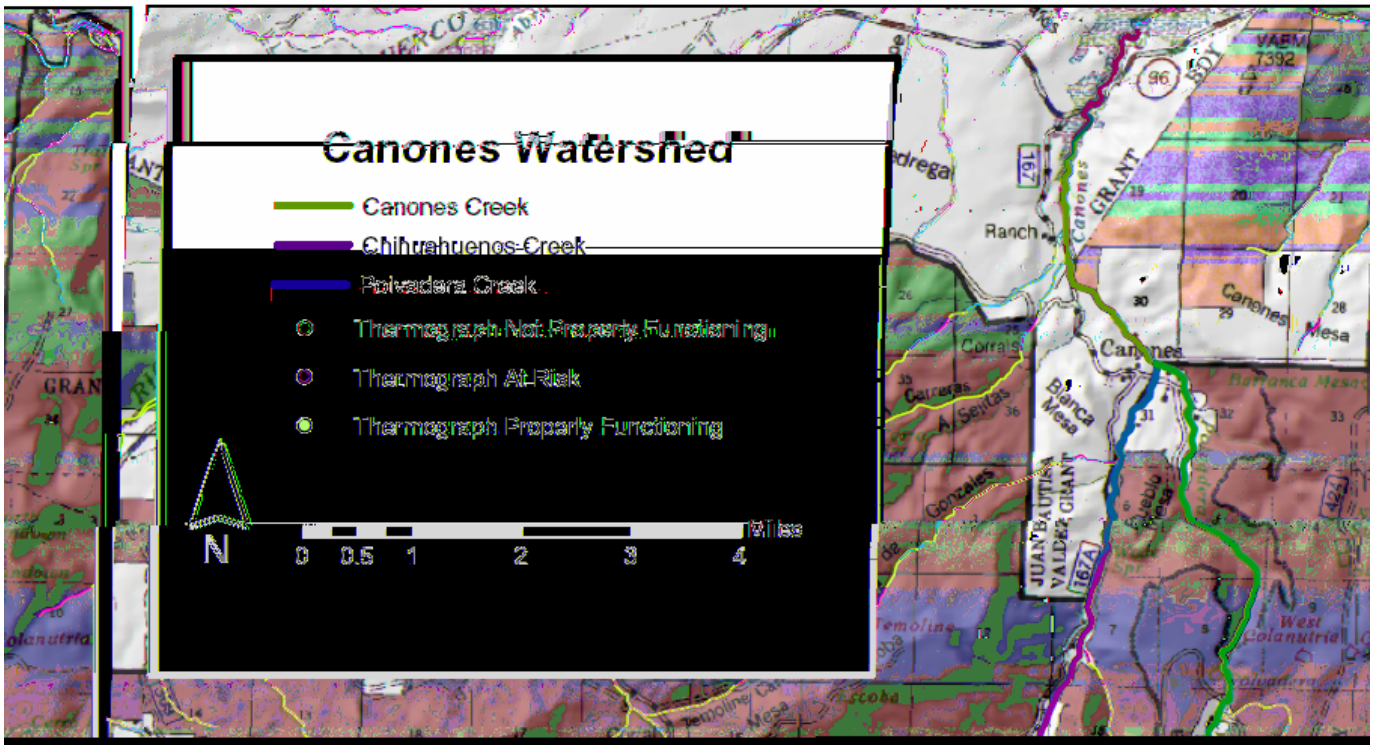
1. Follow the guidelines for stream temperature collection and analysis laid out by NMED in the 2004 State of New Mexico Procedures for Assessing Standards Attainment for the Integrated 303(d)/305(b) Water Quality Monitoring and Assessment Report: Assessment Protocol.
2. Continuous monitoring of streams over a series of years. Thermographs left in a system over several years would record the impacts of changed management plans as well as account better for environmental stochasticity.
3. Studies such as Hubert and Gern (1995) observed a reduction in the fitness of cutthroat populations due to stream temperatures being too low. At this time we are not looking at a low temperature threshold, but in the future this should be explored by monitoring winter and spring temperatures.
4. Life history information on optimum temperatures specific to Rio Grande cutthroat trout has not been researched. A study to identify optimum temperature and lethal limits is needed to further refine appropriate standards for occupied and future RGCT waters.
5. Diurnal difference has been observed to reduce the growth rate of juvenile cutthroat (Meeuwig et al, 2004; Dickerson and Vineyard, 1999), but these studies did not identify what range of change fish can adapt to, what range reduces fitness, and what range is lethal. A study to identify such ranges is needed to analyze diurnal difference.

# Jemez Mountains GMU

Cañones Creek Watershed
Rio Guadalupe Watershed
Upper Jemez River Watershed

Rio de las Vacas valley

on SFNF standards.



# Cañones Creek Watershed

Cañones Creek Watershed is located on the northern flank of the Jemez Mountains and is managed by Española Ranger District, Coyote Ranger District and private landowners. Streams in this system flow primarily south to north and eventually enter the Rio Chama at Abiquiu Reservoir. The watershed's management is guided by the Santa Fe National Forest Land and Resource Management Plan. The watershed has been listed as impaired under Section 303(d) of the Clean Water Act by New Mexico Environment Department. The impairments include turbidity, temperature, fecal coliform, stream bottom deposits, and chronic aluminum (NMED 2003).

Recent stream surveys noted a lack of pool development, increased fines in riffle habitat, accelerated bank instability, lack of large woody debris, and degraded riparian condition. Management activities in the watershed that may be affecting stream temperature include grazing, road construction in the floodplain, unmanaged recreation, historic logging activities, and fuel wood removal (USDA Forest Service 2005(a) and USDA Forest Service 2005(c)).

**Table 3.** Summary of data collected in Cañones Creek watershed

| River | Year Monitored | River Miles Monitored | # of thermo-graphs | NMED Standards | | | SFNF Standards | | | Districts |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | NF | AR | PF | NF | AR | PF | |
| Cañones | 2003 | 11.2 | 3 | 0 | 2 | 1 | 0 | 3 | 0 | Coyote and Española RD |
| Chihuahueños | 2003 | 4.0 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | Coyote RD |
| Polvadera | 2003 | 6.4 | 2 | 0 | 1 | 1 | 0 | 2 | 0 | Española RD |

(NF= not properly functioning, AR= at risk, PF= properly functioning).

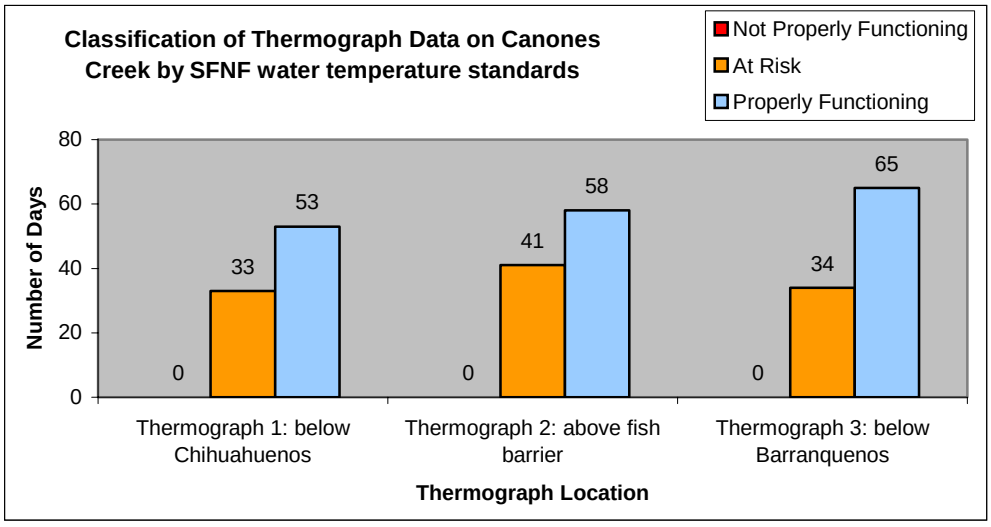
## *Cañones Creek*

Three temperature monitoring stations were established on Cañones Creek (see Figure 1). The stations were not moved for the duration of the monitoring period. Water temperature was monitored from June 16th to October 30th, 2003. Thermographs recorded temperatures at 4-hour intervals for the duration of their time in the creek, providing over 714 temperatures for each site.

The first thermograph station was placed at the beginning of the 2002 stream inventory, just above the confluence with Chihuahueños (Reach 2, River mile 8.3). The next station was located immediately upstream from the human-made fish barrier (Reach 3, RM 9.8). The third station was located above the confluence with Barranqueños Creek (Reach 4, RM 11.4).

Thermograph data collected between June 16th and September 30th was used to determine water quality. When SFNF standards are applied, all three stations are **at risk**. None of the sites were classified as not properly functioning and all of the sites had more properly functioning days than days at risk (see Figure 2).

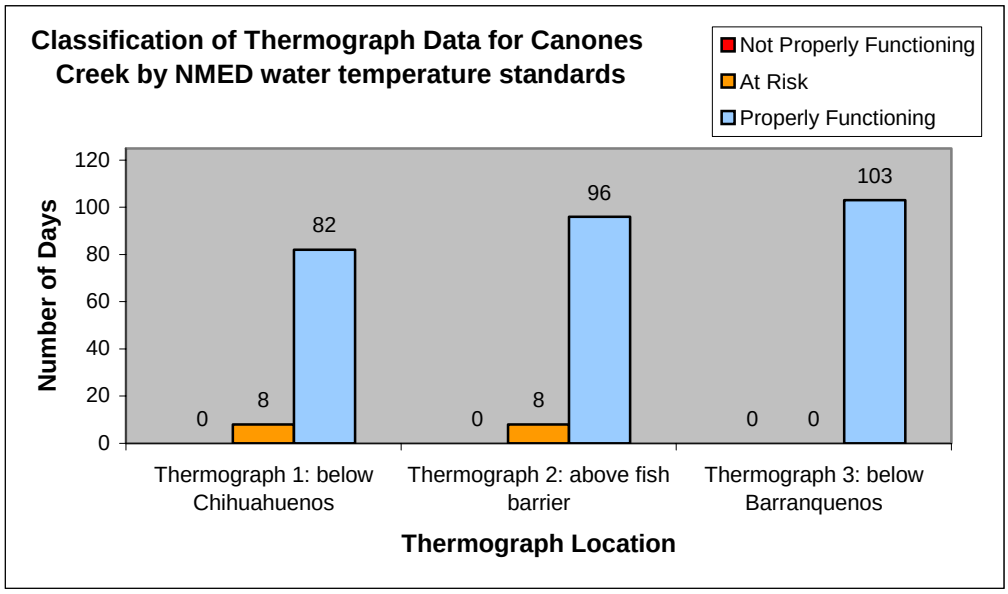
**Figure 2**. Comparison of days not properly functioning, at risk, and properly functioning at three thermograph sites in Cañones Creek between June 16th and September 30th, 2003. Water temperature categories are defined by SFNF Water Quality Temperature Standards are based on seven-day average maximum.




Two stations recorded **at risk** days when classified by NMED standards: Above the confluence with Chihuahueños Creek and above the Fish Barrier (see Figure 3). Both sites had significantly fewer days at risk than properly functioning. No days were classified as not properly functioning during the monitoring period.

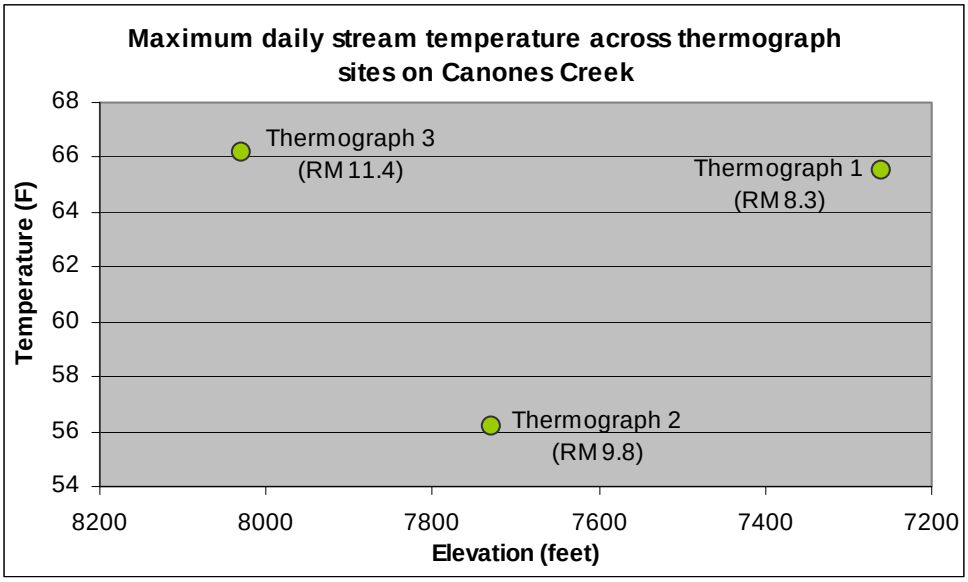
Looking at stream temperatures across elevation can also distinguish areas in need of temperature mitigation. On a typical system, temperatures should increase as elevation decreases. Cañones Creek does not follow this pattern. On July 31st, 2003 a maximum stream temperature of 66.2°F was recorded at Thermograph Station 3 (elevation 8030'). This temperature was slightly higher than the 65.5°F recorded at Thermograph Station 1 (elevation 7260', see Figure 4). The lowest maximum temperature of 66.8°F on July 31st was recorded at Thermograph Station 2. This may be due in part to natural conditions (upwellings, coldwater springs, differing valley formations and aspect, etc.).

**Figure 3**. Comparison of days not properly functioning, at risk, and properly functioning in Cañones Creek between June 18th and September 30th, 2003. Water temperature categories defined by NMED Water Quality Temperature Standards are based on three-day average maximum.



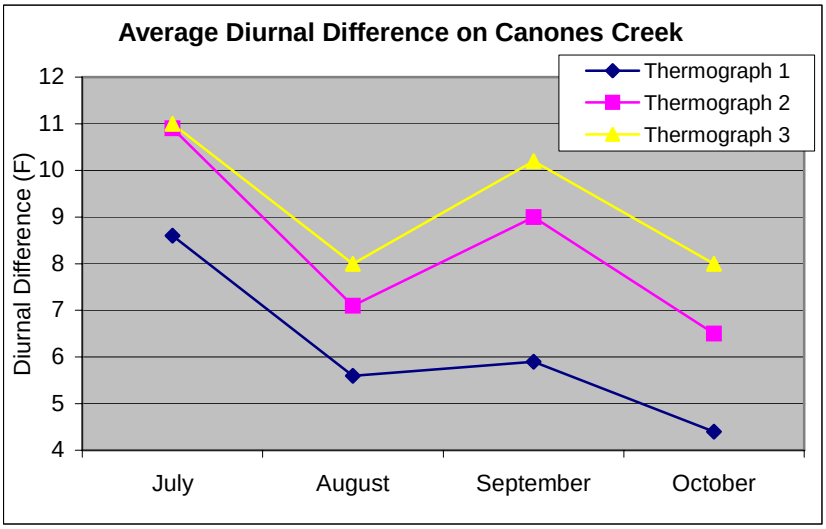

Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. On July 9th, 2003, a particularly warm day, diurnal fluctuations ranged from 16.6 F at the Fish Barrier Site to 13 F at the confluence with Chihuahueños. Thermograph station 1 at the confluence with Chihuahueños consistently had the lowest daily diurnal differences (see Figure 5). Thermograph station 3, though further up the stream, had the highest diurnal differences.

**Figure 4**. Maximum stream temperatures recorded on July 31st, 2003 across the three thermograph stations on Cañones Creek.




The **at risk** classification of multiple sites by both the Forest and NMED water quality standards implies that water temperature should be a management consideration for Cañones Creek. Another warning sign was the break in the relationship between temperature and elevation. Temperature mitigating strategies should be applied to protect the integrity of the coldwater fishery.

**Figure 5**. Diurnal difference averaged by month for the three thermograph stations on Cañones Creek.



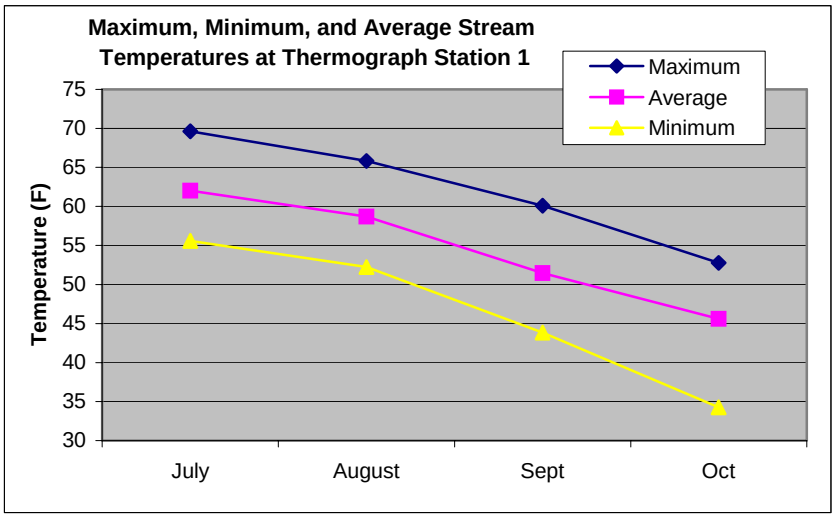

A stream inventory survey in 2002/2003 found Cañones Creek to be fairly pristine. The steep canyon walls along most of the surveyed stretch of the river keep out most human recreators and cattle. The only portion of the creek significantly impacted by human activities and cattle use is the headwaters. Slumping and exposed banks and lack of riparian shade all impact this stretch of Cañones Creek (USDA Forest Service 2005 (a)). The habitat degradation apparent in the upper end of the stream could explain why Thermograph Station 3 was warmer than Thermograph Station 1, even though it was placed at a higher elevation.

Surveyors recommended the headwaters be m

**Photo 4.** Small falls forming plunge pool at thermograph station 1 (30-Jun-03).

Average monthly diurnal difference also peaked in July (see Figure 5). The maximum daily diurnal difference of 12.9°F was observed on July 12th, 2003. The minimum daily diurnal difference of 2.0°F occurred on August 28th, 2003.

**Figure 6**. Maximum, Minimum, and average temperatures for each month for the thermograph station below confluence with Chihuahueños Creek.



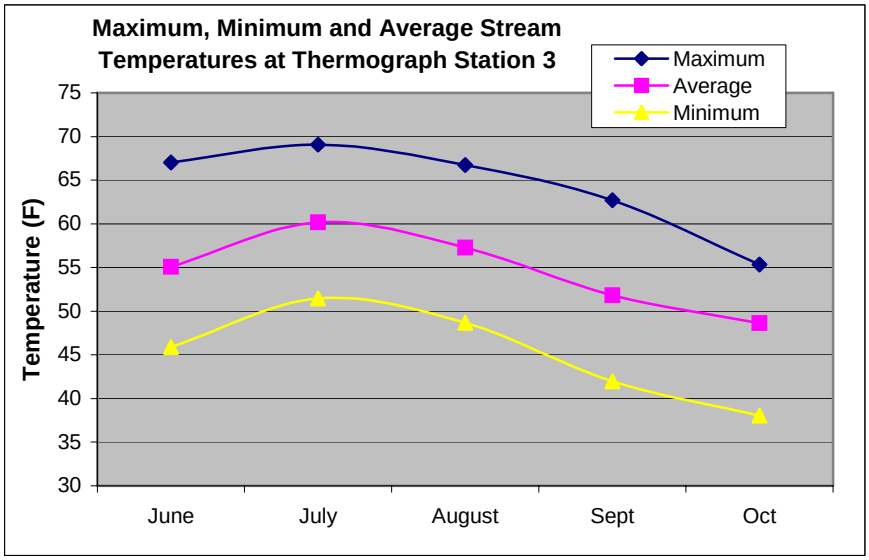

*Thermograph Station 2*: above Barrier
*Elevation*: 7730'
*Stream Mile*: 9.8

Thermograph Station 2 monitored 1.6 stream miles. This section of Cañones Creek enters a tighter steeper and canyon system. National Scenic Trail 82 parallels the creek for the entire section. The data collected in 2003 determined Cañones Creek above the man-made barrier was **at risk** for 8 of the 104 days recorded by NMED standards (7.8% of days). The site was considered **at risk** for SFNF standards 41 out of 99 days recorded (45.1% of days).

**Photo 6.** Thermograph #3 deployed in shallow pool (16-Jun-03).

Maximum stream temperatures were recorded in July (see Figure 8). On July 18th, stream temperature peaked at 69.1°F. After July, stream temperatures decreased steadily until the thermograph was pulled in October.

**Figure 8**. Maximum, minimum and average temperatures for each month for thermograph station below the confluence with Barranqueños Creek.




Average monthly diurnal difference also peaked in July at 11°F. A second peak occurred in September when the average diurnal difference rose back up to 10.2°F (see Figure 5). The maximum daily diurnal difference of 18°F occurred on June 26th, 2003. The minimum daily diurnal difference of 3.4°F was observed on October 2nd, 2003.

## *Chihuahueños Creek*

Two temperature monitoring stations were established on Chihuahueños Creek (see Figure 1). The stations were not moved for the duration of the monitoring period. Water temperature was monitored from July 11th to October 29th, 2003. Thermographs recorded temperatures at 4-hour intervals providing over 666 temperatures for each site.

The first thermograph station was placed near the mouth of Chihuahueños creek, (River Mile 0.0). This station did not record properly, so temperature data is not available from this location. Another thermograph was deployed at this site in 2004. The second station was located at the Forest Road 448 stream crossing, RM 3.6, elev. 8640' (see Photo 7). Station 2 monitored 4.0 stream miles. This section of Chihuahueños Creek flows through a steep canyon for most of its length. The valley floor in the upper portion widens and then constricts again near the headwaters.

**Photo 7**. Shallow pool below which thermograph #2 was deployed at FR 448 crossing. Blue tape in creek marks thermograph location (11-Jul-03).

Thermograph data collected between July 11th and September 30th was used to determine water quality. When SFNF standards are applied, Chihuahueños Creek at FR 448 was **at risk** 11 out of 76 days, or 14.5% of recorded days (see Figure 9). The station had no at risk or not properly functioning days by NMED standards (see Figure 10).

**Figure 9.** A comparison of not properly functioning, at risk, and properly functioning days for Chihuahueños Creek at Forest Road 448 between July 11th and September 30th, 2003. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on seven-day average maximum.

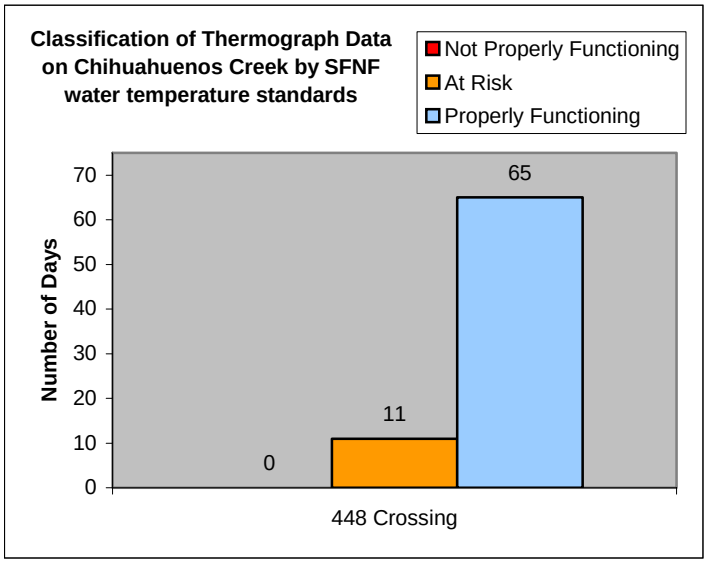
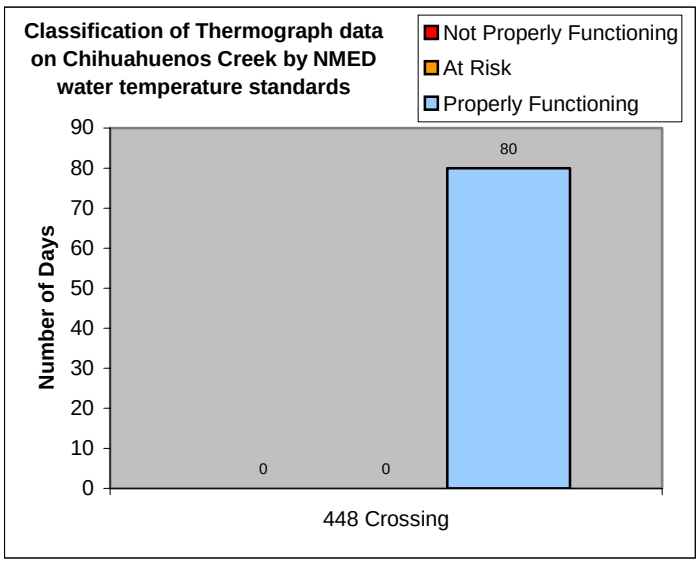
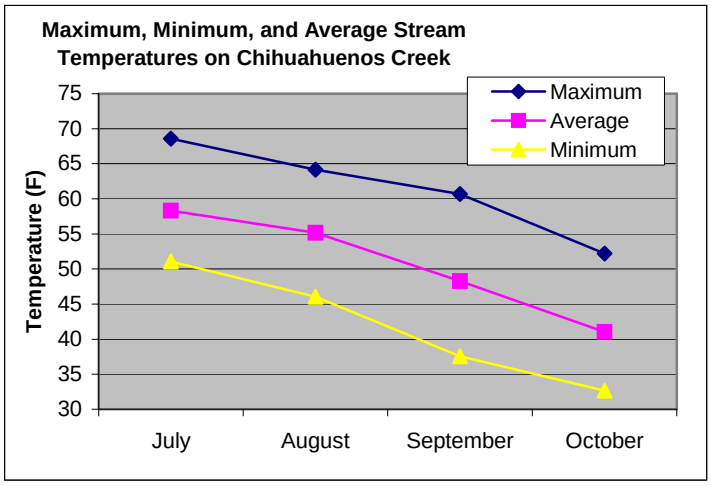



**Figure 10.** A comparison of not properly functioning, at risk, and properly functioning days for Chihuahueños Creek at Forest Road 448 between July 11th and September 30th, 2003. Water temperature categories defined by NMED Water Quality Temperature Standards are based on three-day average maximum.



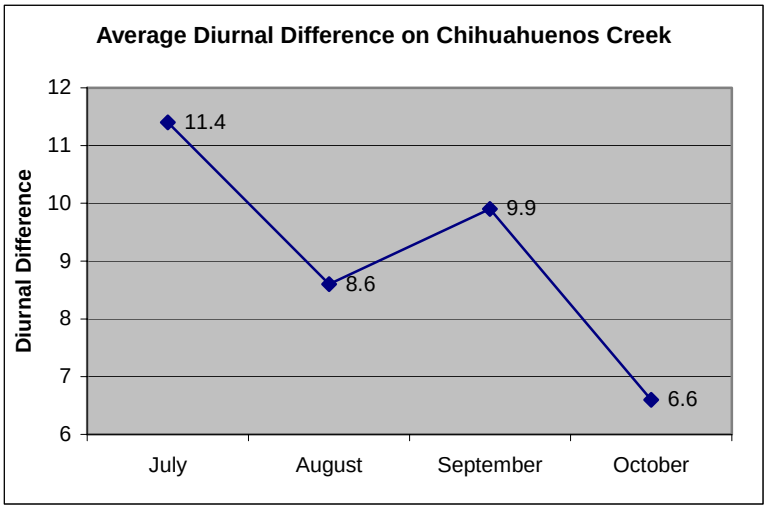

Maximum stream temperatures at the Forest Road 448 crossing were recorded in July. Temperature peaked on July 13th, 2003 reaching 68.6°F. After July, temperatures decreased steadily until the thermograph was pulled in October (see Figure 11).

**Figure 11.** Maximum, minimum and average for each month for the thermograph station at the FR 448 road crossing of Chihuahueños Creek.




Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. The maximum daily diurnal difference of 15.8°F was recorded on July 13th. The minimum daily diurnal difference of 1.2°F occurred on October 26th. Average monthly diurnal difference peaked in July at 11.4°F and again in September at 9.9°F (see Figure 12).

**Figure 12**. Diurnal difference averaged by month for the thermograph station on Chihuahueños Creek.



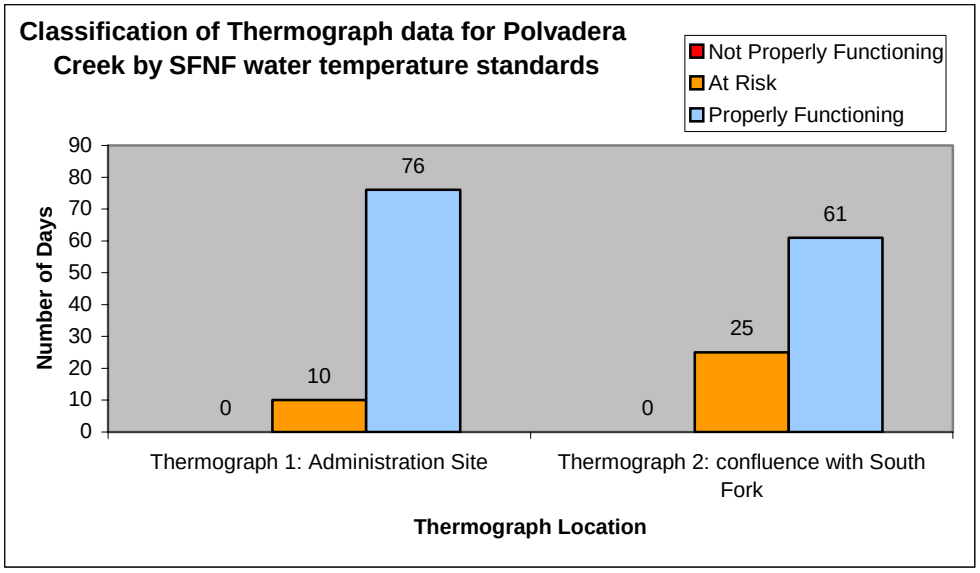

The **at risk** classification by SFNF water quality standards implies that water quality should be a management consideration for Chihuahueños Creek. Temperature mitigations strategies should be applied to protect the integrity of the cold water fishery. A stream inventory is scheduled to be conducted on this creek in 2005 to identify the factors influencing stream temperature.

## *Polvadera Creek*

Two temperature monitoring stations were established on Polvadera Creek (see Figure 1). The stations were not moved for the duration of the survey. Water temperature was monitored from July 1st to October 8th, 2003. Thermographs recorded temperatures at 4-hour intervals providing over 588 temperatures for each site. The first station was placed at an Administration Site (River Mile 6.2). The second station was located just above the confluence with South Fork Polvadera Creek (RM 8.4).

Thermograph data collected between July 1st and September 30th, 2003 was used to determine water quality. When SFNF standards are applied both stations were **at risk**, although both had significantly more days properly functioning than at risk (see Figure 13).

**Figure 13.** Comparison of days not properly functioning, at risk, and properly functioning at two thermograph stations in Polvadera Creek between July 1st and September 30th, 2003. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on seven-day average maximum.

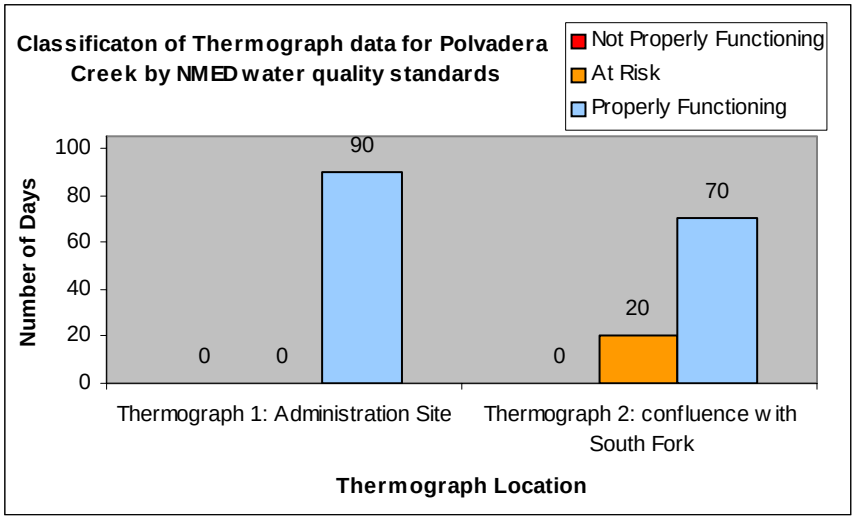



The thermograph station above the confluence with South Fork recorded **at risk** days when classified by NMED standards. The number of at risk days for this station was again significantly less than the number of properly functioning days. No days for either site were classified as not properly functioning (see Figure 14).

Looking at stream temperatures across elevation can also distinguish areas in need of temperature mitigation. On a typical system, stream temperature should increase as elevation decreases. Polvadera Creek follows this pattern. On July 31st, Thermograph Station 2 (elevation 8000') exhibited a maximum temperature of 65.8°F, whereas Thermograph Station 1 (elevation 7860') had a maximum temperature of 67.2°F.

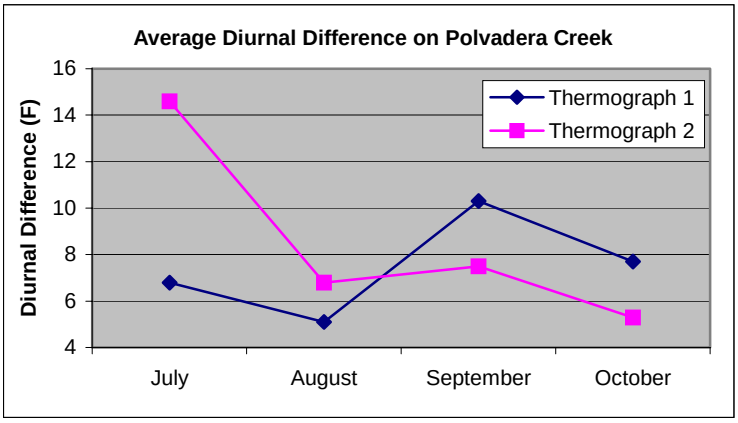
Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. Again on July 31st on Polvadera Creek, diurnal difference ranged from 13.5°F at Thermograph Station 2 to 8.5°F at Thermograph Station 1. Diurnal temperature fluctuations were significantly greater at the Thermograph Station 2 during July and August (see Figure 15).

**Figure 14**. Comparison of days not properly functioning, at risk, and properly functioning at two thermograph stations in Polvadera Creek between July 1st and September 30th, 2003. Water temperature categories defined by NMED Water Quality Temperature Standards are based on three-day average maximum.




The **at risk** classification of both sites by SFNF water quality standards and one site by NMED standards implies that water quality should be a management consideration for Polvadera Creek. Temperature mitigations strategies should be applied to protect the integrity of the cold-water fishery.

**Figure 15**. Diurnal difference averaged by month for two thermograph stations on Polvadera Creek.




A stream inventory was conducted in the summer of 2004. Above Thermograph Station 2, surveyors noted intense cattle use in the meadow that runs along the stream approximately a half-mile. This section of stream had trampled banks and little streamside vegetation to provide shade. The vegetation in this meadow was on average three inches high. Thermograph station 1 was cooler because the stream runs through a shaded canyon for about a quarter mile before it comes out into a less impacted meadow. This meadow had more alder, willow and herbaceous vegetation providing shade. It also had less evidence of recent cattle use, although the exclosure fence has broken sections where cows could get through (USDA Forest Service 2005(c) *pending*).

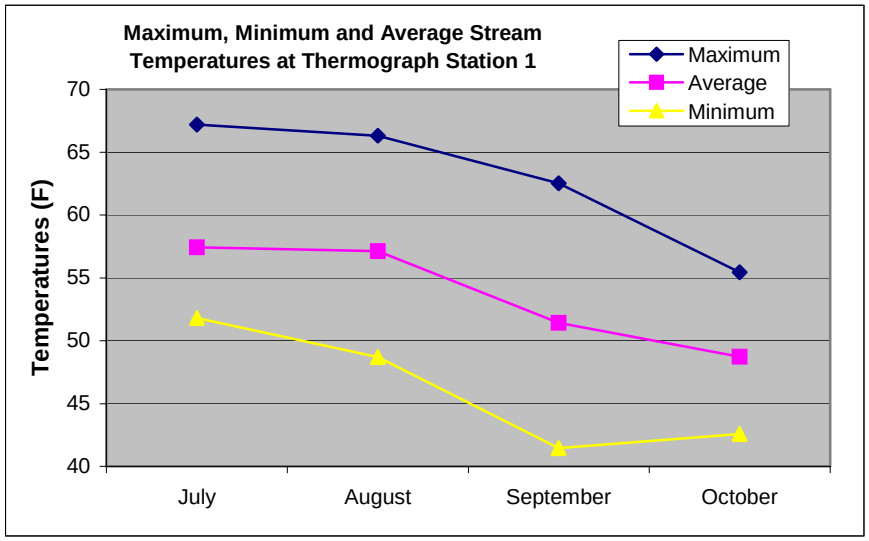
*Thermograph Station 1*: Administration Site
*Elevation*: 7860'
*Stream Mile*: 6.2

Thermograph Station 1 monitored 2.2 stream miles. This section of Polvadera Creek begins in an open meadow system which gradually converts to a canyon. Forest Service Trail 107 parallels the creek for most of this length. The data collected in 2003 found the site **at risk** by SFNF standards 10 out of the 86 days recorded (11.6% of the days). The site was **properly functioning** all 90 days by NMED standards.

**Photo 8.** Low flow of Polvadera creek at Administration site where thermograph #1 was placed (30-Jun-03).

Maximum stream temperatures were recorded in July. On July 24th, stream temperature peaked at 67.2°F. After July, stream temperature decreased steadily until the thermograph was pulled in October (see Figure 16).

**Figure 16**. Maximum, minimum and average temperatures for each month for the thermograph station located at the administration site.



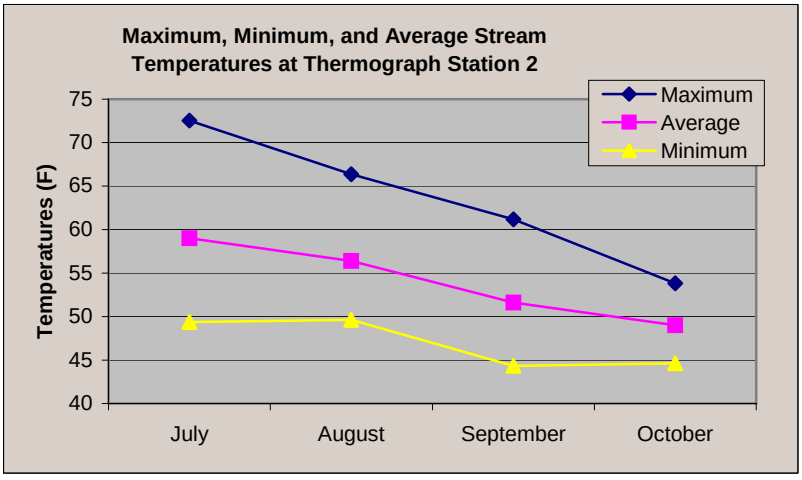
Average monthly diurnal difference peaked in September (see Figure 15). Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. The maximum daily diurnal difference of 13.7°F was observed on September 22nd. The daily minimum diurnal difference of 1.1°F occurred on both July 15th and 16th.

*Thermograph Station 2*: South Fork Confluence
*Elevation*: 8000'
*Stream Mile*: 8.4

**Photo 9.** Polvadera Creek above South Fork confluence. Looking downstream from where thermograph #2 was placed (30-Jun-03).

Thermograph Station 2 monitored 4.2 stream miles. This section of Polvadera Creek enters a tight canyon system after a short length in an open meadow near the confluence with South Fork. The data collected in 2003 classified this section of stream as **at risk** by both SFNF and NMED water temperature standards. Twenty-five (25) days out of 86 were **at risk** by SFNF standards (29.1% of days). Twenty (20) days out of 90 total days were **at risk** by NMED standards (22.2% of days).

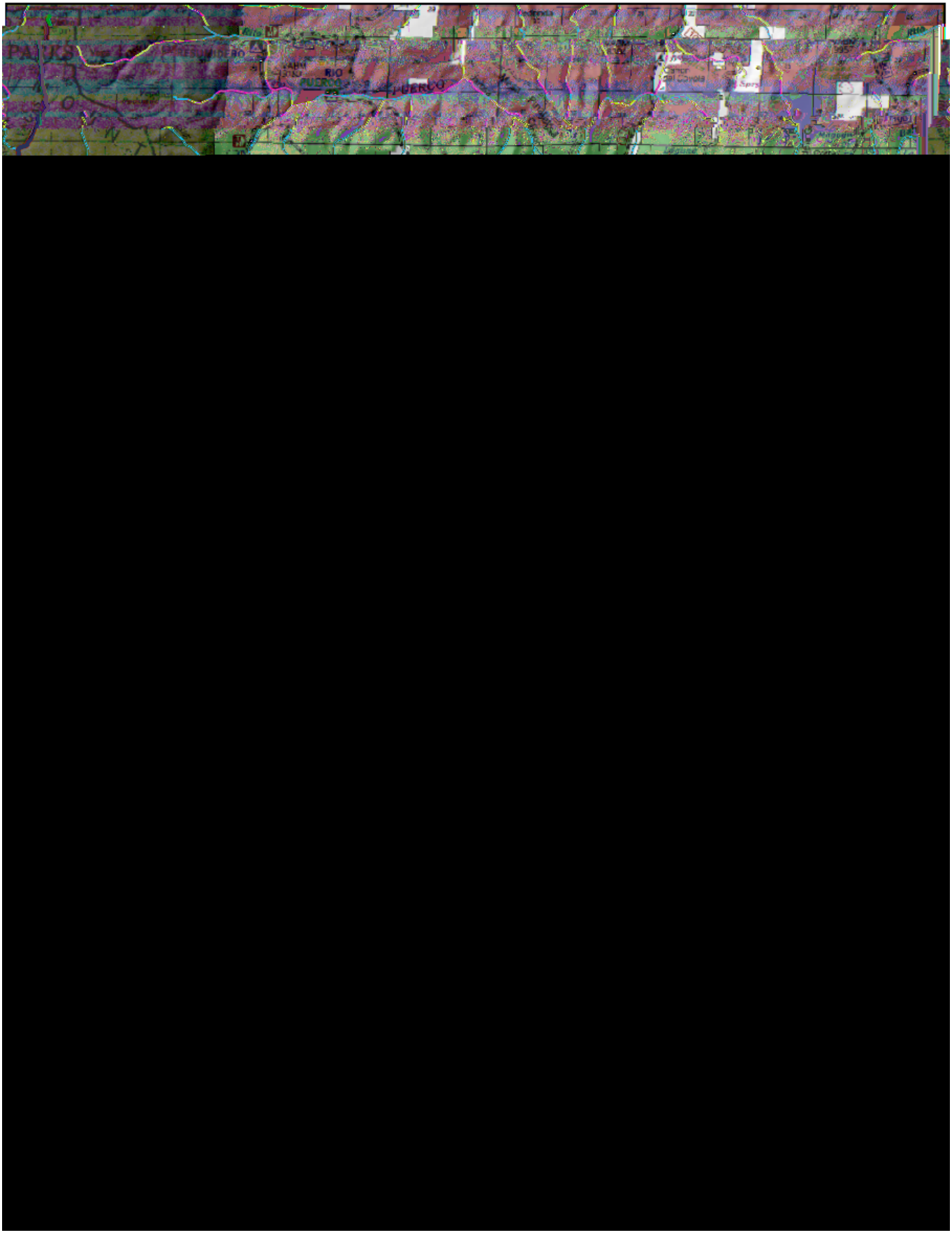
**Figure 17**. Maximum, minimum, and average temperatures for each month for the thermograph station above the South Fork confluence.



Maximum stream temperatures were observed in July (see Figure 17). The maximum daily temperature of 72.6°F was recorded on July 9th. After July, temperatures decreased steadily until the thermograph was pulled in October.

Average monthly diurnal difference also peaked in July (see Figure 15). Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. The maximum daily diurnal difference of 20.4°F occurred on July 24th. The minimum daily diurnal variation of 2.8°F was observed on August 28th.

Figure 18. Map of thermograph locations in Guadalupe Watershed. Stream temperature classifications are based on SFNF standards.



# Guadalupe Watershed

The Guadalupe Watershed is located on the southern side of the Jemez Mountains and is managed by the Jemez, Coyote, and Cuba Ranger Districts; private landowners; New Mexico Department of Game and Fish and New Mexico State Parks. Streams flow mostly north to south and eventually enter into the Jemez River. The watershed's management is guided by Santa Fe National Forest Land and Resource Management Plan and special designation as Wilderness. The watershed has been listed as impaired under Section 303(d) of the Clean Water Act by New Mexico Environment Department. The impairments include turbidity, chronic aluminum, stream bottom deposits, and stream temperature (NMED 2003).

Recent stream surveys noted a lack of pool development, increased fines in riffle habitat, accelerated bank instability, lack of large woody debris, and degraded riparian condition. Management activities in the watershed that may be affecting stream temperature include grazing, road construction in the floodplain, historic logging activities, fuel wood removal, recreational activities including developed and dispersed camping, hiking, fishing, and ATV vehicle use (USDA Forest Service 2003(d), USDA Forest Service 2004, USDA Forest Service 2005(e)) .

**Table 4.** Summary of data collected in Guadalupe watershed.

| River | Year Monitored | River Miles Monitored | # of thermo-graphs | NMED | | | SFNF Standards | | | Districts |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | NF | AR | PF | NF | AR | PF | |
| Rio Cebolla | 2001 | 21.8 | 4 | 0 | 2 | 2 | 4 | 0 | 0 | Jemez and Coyote RD |
| Rio de las Vacas | 2001 | 25.1 | 2 | 0 | 1 | 1 | 1 | 1 | 0 | Jemez and Cuba RD |
| | 2003 | 25.1 | 2 | 2 | 0 | 0 | 2 | 0 | 0 | |
| Rito Peñas Negras | 2003 | 9.5 | 2 | 1 | 1 | 0 | 1 | 1 | 0 | Cuba RD |
| Rito Café | 2003 | 2.4 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | Cuba RD |

(NF= not properly functioning, AR= at risk, PF= properly functioning)

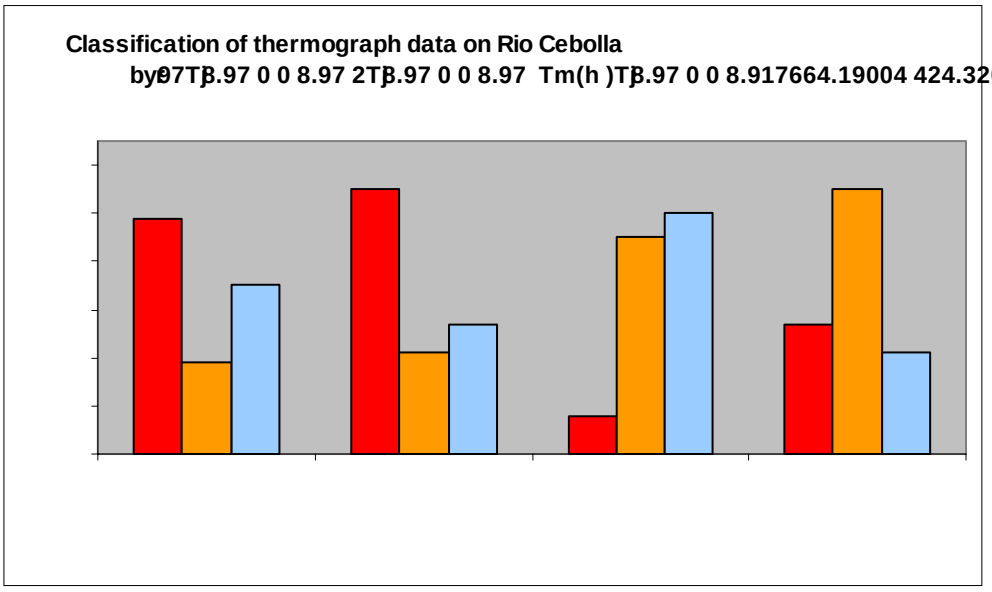
## *Rio Cebolla*

Four temperature monitoring stations were established on Rio Cebolla (see Figure 18). The stations were not moved for the duration of the monitoring period. Water temperature in Rio Cebolla was recorded from June 14th to October 1st, 2001. Thermographs recorded temperatures at 4-hour intervals providing over 654 temperatures for each site.

The first thermograph was placed near the mouth of Rio Cebolla, at the confluence with Rio de las Vacas (Reach 1 of 2001 survey, River Mile 0.0). The second thermograph was placed downstream of Fenton Lake (Reach 3, RM 5.0). The third thermograph was placed upstream of Fenton Lake (Reach 5, RM 7.1). The fourth thermograph was placed above Seven Springs State Fish Hatchery (Reach 7, RM 10.9).

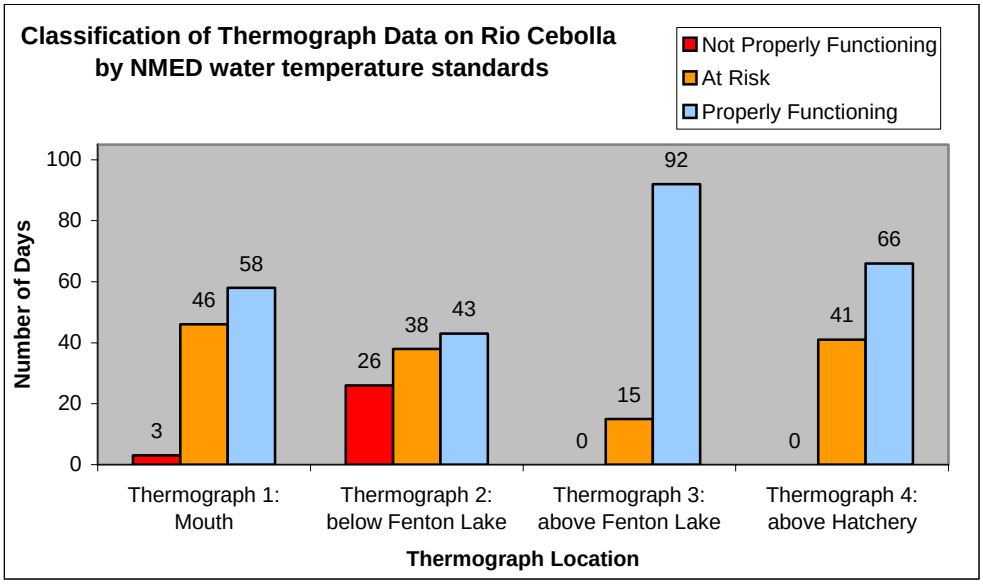
Thermograph data collected between June 14th and September 30th, 2001 was used to determine water quality. When SFNF standards are applied, all 4 sites were **not properly functioning** (see Figure 19). All the sites also had at risk days and properly functioning days. The two stations below Fenton Lake had more not properly functioning days than properly functioning days.

**Figure 19**. A comparison of not properly functioning, at risk, and properly functioning days at four thermograph sites on Rio Cebolla between June 14th and September 30th, 2001. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on a seven-day average maximum.



and Thermograph Station 3 is Fenton Lake State Park. Over this 2.1-mile stretch temperature increased 7.2°F, indicating that Fenton Lake is influencing stream temperature.

**Figure 20**. A comparison of not properly functioning, at risk, and properly functioning days at four thermograph sites on Rio Cebolla between June 14th and September 30th, 2001. Water temperature categories defined by NMED Water Quality Temperature Standards are based on a three-day average maximum.




Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. On July 31st, 2001 diurnal differences were greatest at the two sites above Fenton Lake (12.6°F above the hatchery and 10.8°F above the lake). At the thermograph station just below the lake the diurnal difference was 8.8°F and at the mouth it was 7.5°F. Looking at diurnal differences averaged by month across the 4 sites demonstrated a similar pattern (see Figure 22). Diurnal differences were always greatest at the Thermograph Station 4 (above the hatchery). The other three stations showed similar numbers in June and July, but in August and September the greatest diurnal differences for the upper three stations was to the 4th station were recorded at Thermograph Station 3.

**Figure 21**. Maximum stream temperatures on July 31st, 2001 across four thermograph station of Rio Cebolla.

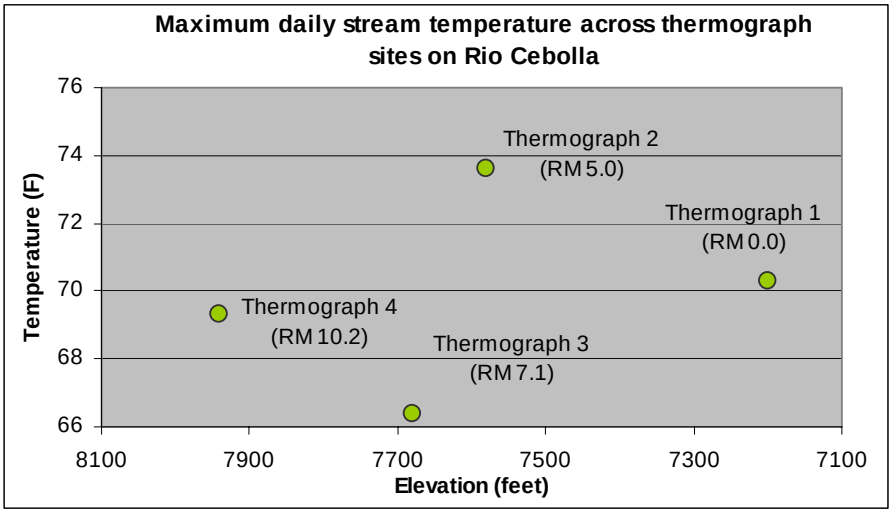
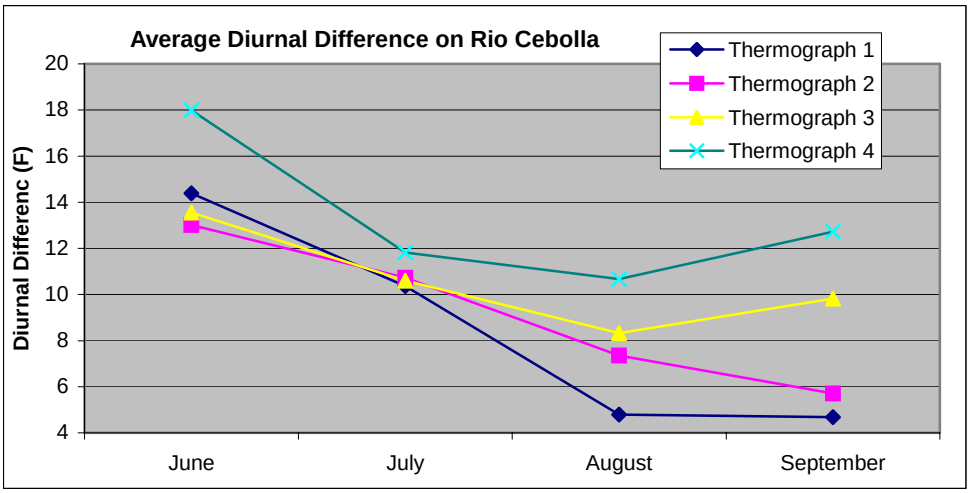


**Figure 22**. Diurnal difference averaged by month across four thermograph stations on Rio Cebolla.




Water quality should be a management consideration for Rio Cebolla. This is indicated by the **not properly functioning** classification of all four sites by SFNF standards, the classification of two sites as **at risk** and two sites as **not properly functioning** by NMED standards, and the break in the relationship between temperature and elevation. Temperature mitigations strategies should be applied to protect the integrity of the cold-water fishery.

Fenton Lake is having a conclusive influence on stream temperatures. This is drawn from data analysis comparing the two stations directly above and below the lake and is further accentuated by Figure 21. The water coming out of Fenton Lake is much warmer than the water entering it. Fenton Lake has a surface drawing dam, meaning that the warmer surface waters flow out of the reservoir. The affect of Fenton Lake on stream temperature will have to be studied further to determine what impacts it is having on fish populations downstream. Two additional factors that have or will affect conditions at Fenton Lake: 1) Post-fire sediment and ash delivery from Lake Fire (2002); and 2) State Highway 126 future reconstruction will alter the wetland immediately upstream from the lake (C. Van Dorn, personal communication, 2005).

A stream inventory of Rio Cebolla was conducted in 2001. Surveyors recommended planting native species in the riparian zone to increase bank stability and streamside shade. Grazing practices should also be managed along the Cebolla to protect the riparian zone. They also recommended limiting the use of dispersed trails and campsites through location, designation, and/or regulations (USDA Forest Service 2003(d)). A program called Respect the Rio has been implemented to limit the impact of dispersed camping on the river in the most heavily impacted corridor. This program involves regulating dispersed camping and educating campers. In addition, an intensive willow planting program started in 2004 coupled by the completion of a 5-mile riparian protection fence in the upper Cebolla. For more information on this project's methods and goals refer to the Respect the Rio Annual Report 2003 and 2004 (USDA Forest Service).

*Thermograph Station 1*: Mouth
*Elevation*: 7200'
*Stream Mile*: 0.0

Thermograph Station 1 monitored 5.0 stream miles. This section of Rio Cebolla flows through a meadow system that sees high visitor use. Forest Road 376 parallels most of this section of stream. Thermograph data collected in 2001 determined Rio Cebolla at the mouth was **not**

**properly functioning** by both NMED and SFNF standards. Forty-nine (49) days were **not properly functioning** (47.6%) and 19 days were **at risk** (18.4%) out of 103 days by SFNF standards. By NMED standards 3 days were **not properly functioning** (2.8%) and 46 days were **at risk** (43.0%) out of 107 days.

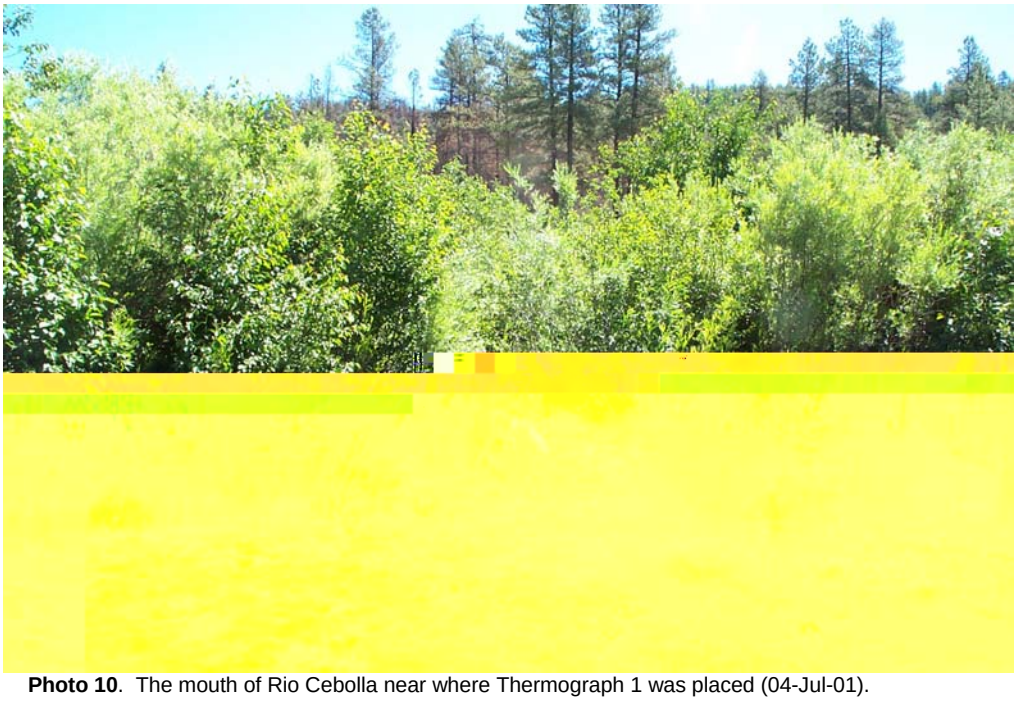
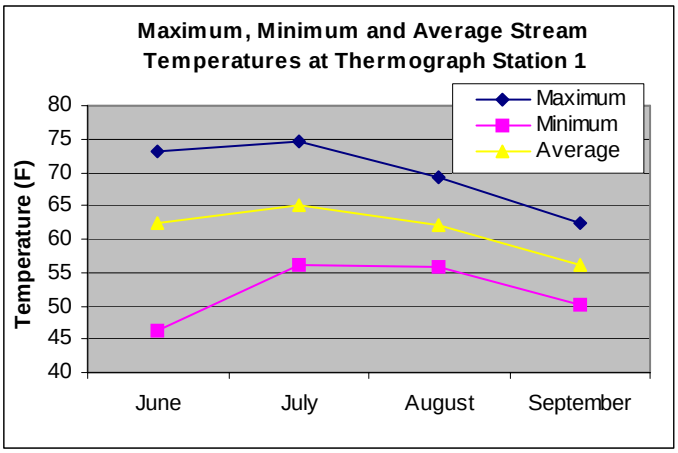


**Photo 10**. The mouth of Rio Cebolla near where Thermograph 1 was placed (04-Jul-01).

Maximum stream temperatures were recorded in July (see Figure 23). Temperature peaked at 74.5°F on July 7th and declined steadily from there until the thermograph was pulled in October.

**Figure 23**. Maximum, minimum and average temperatures for each month for the thermograph station at the mouth.




Average monthly diurnal difference peaked in June at 14.4°F (see Figure 22). The maximum daily diurnal difference of 18.5°F occurred on July 19th. The minimum daily diurnal difference of 1.4°F occurred on August 13th.

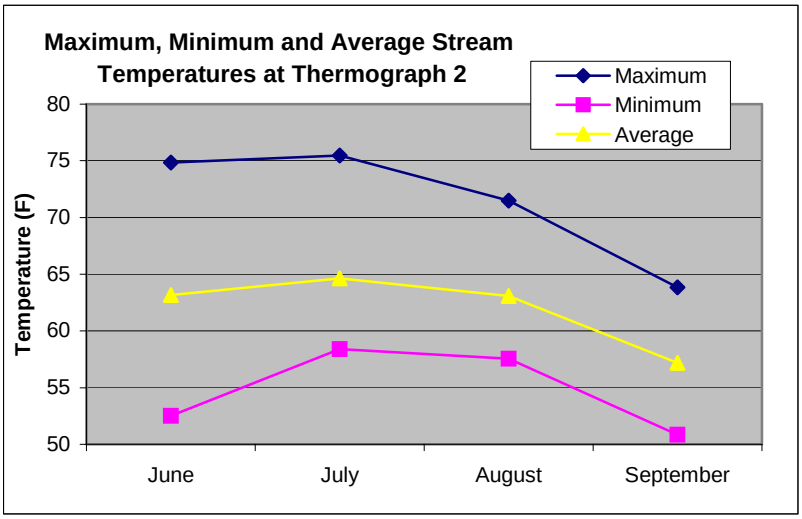
*Thermograph Station 2*: Below Fenton Lake
*Elevation*: 7580'
*Stream Mile*: 7.1

Thermograph Station 2 monitored 2.1 stream miles. This section of Rio Cebolla flows through Fenton Lake State Park. A portion of this section passes through the man-made Fenton Lake. Thermograph data collected in 2001 determined Rio Cebolla below Fenton Lake was **not properly functioning** by both NMED and SFNF standards. Fifty-five (55) days were **not properly functioning** (53.4% of days) and 21 (20.4% of days) days were **at risk** out of 103 days by SFNF standards. By NMED standards 26 days (24.3%) were **not properly functioning** and 38 days were **at risk** (35.5%) out of 107 days.

**Photo 11**. Fenton Lake below which Thermograph 2 was placed (30-Jul-01).

Maximum stream temperatures were recorded in July (see Figure 24). Temperatures peaked at 75.5°F in July and declined steadily from there until the thermograph was pulled in October.

**Figure 24**. Maximum, minimum and average temperatures for each month for the thermograph station Below Fenton Lake.



Average monthly diurnal difference peaked in June at 13.0°F (see Figure 22). The maximum daily diurnal difference of 16.4°F was recorded on July 16th. The minimum daily diurnal difference of 2.8°F occurred on September 14th.

*Thermograph Station 3*: Above Fenton Lake
*Elevation*: 7680'
*Stream Mile*: 7.1

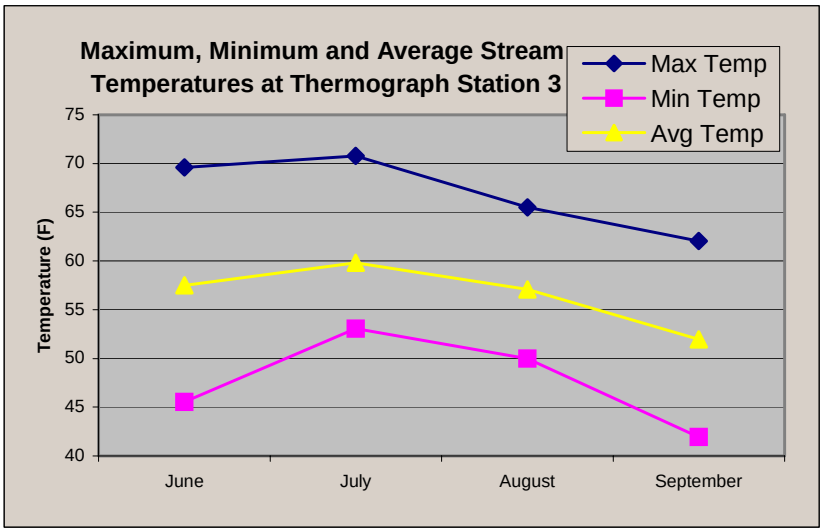
Thermograph Station 3 monitored 3.2 stream miles. This section of Rio Cebolla is primarily on private and state managed lands and is fed by a series of springs and Calaveras Creek. It passes through the community of Seven Springs and the Seven Springs State Fish Hatchery.

Thermograph data collected in 2001 identified Rio Cebolla above Fenton Lake as **not properly functioning** by SFNF standards. Eight days were not properly functioning (7.8%) and 45 days were at risk (43.7%) out of 103 days. By NMED standards the site was **at risk**, 15 days at risk (14.0%) out of 107.

**Photo 12.** Rio Cebolla in meadow above Fenton Lake near where Thermograph 3 was placed (01-Aug-01).

Maximum stream temperatures were recorded in July (see Figure 25). Maximum stream temperature was recorded at 70.8°F in July. Temperatures then decreased steadily until the thermograph was pulled in September.

**Figure 25**. Maximum, minimum and average temperature for each month for the thermograph station Above Fenton Lake.




Average monthly diurnal difference peaked in June at 13.6°F (see Figure 22). The maximum daily diurnal difference of 18.9°F was recorded on June 16th. The minimum daily diurnal difference of 4.5°F occurred on June 26th.

*Thermograph Station 4*: Above Seven Springs Hatchery
*Elevation*: 7940'
*Stream Mile*: 10.2

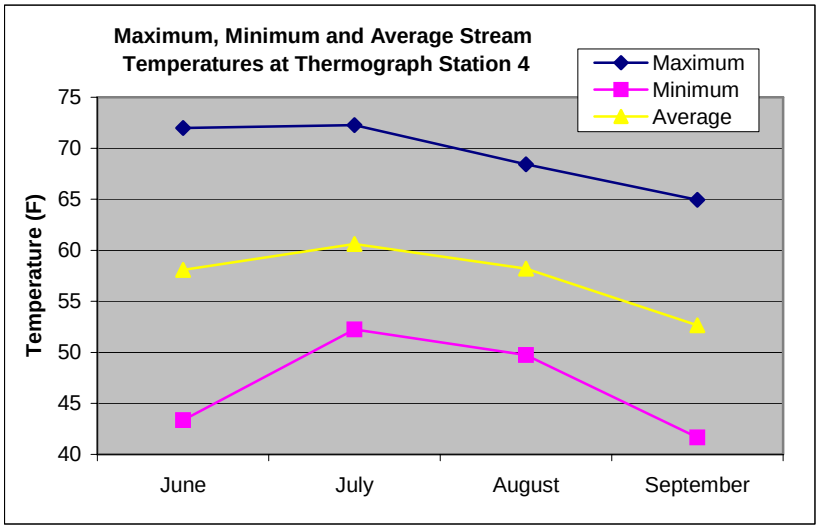
Thermograph Station 4 monitored 10.9 stream miles. This section of Rio Cebolla starts in an open valley that narrows towards the headwaters. Thermograph data collected in 2001 determined Rio Cebolla at Seven Springs Hatchery was **not properly functioning** by SFNF standards. Twenty-seven (27) days were **not properly functioning** (26.2% of days) and 55 days were **at risk** (53.4% of days) out of 103 day by SFNF standards. By NMED standards the station was **at risk**. Forty-one (41) days were **at risk** (38.3% of days) out of 107 days.

Maximum stream temperatures were recorded in July (see Figure 26). Temperature peaked at 73.3°F in July and decreased steadily until the thermograph was pulled in October.

Average monthly diurnal difference peaked in June at 18.0°F (see Figure 22). The maximum daily diurnal difference of 24.9°F occurred on June 16th. The minimum daily diurnal difference of 5.6°F occurred on July 17th.

**Photo 13**. Typical stretch of stream near where Thermograph 4 was placed (21-Aug-01).

**Figure 26**. Maximum, minimum and average temperatures each month for the thermograph above Seven Springs.



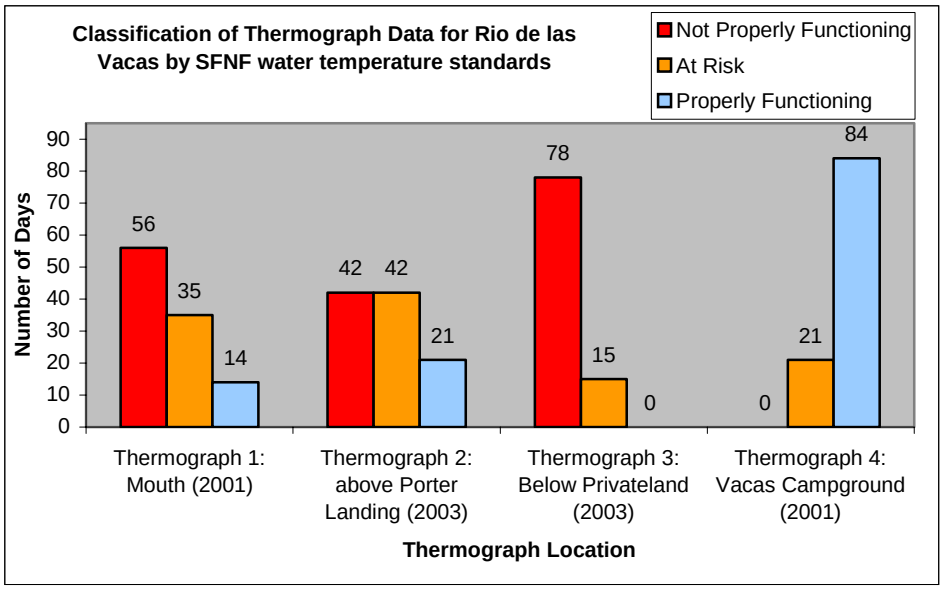
## *Rio de las Vacas*

Water temperature in Rio de las Vacas was monitored in 2001 and 2003 (see Figure 18). The stations were not moved for the duration of the monitoring period. In 2001 two temperature stations were established from June to October 2001. In 2003, four stations were established, measuring temperature from June 12th through October 23rd. Thermographs recorded temperatures at 4-hour intervals.

In 2001, the first thermograph station was located near the confluence with Rio Cebolla (Reach 1 of the 2001 survey, River Miles 0.0). The second station was placed near the Las Vacas Campground (Reach 9, River Mile 14.8). In 2003, the first temperature station was also placed near the confluence with Rio Cebolla (Reach 1, River Miles 0.0). The second station was placed 2 miles above the confluence (Reach 2, River Miles 1.8). The third station was established below a stretch of private land (Reach 6, RM 9.6). The final station was placed at the Las Vacas Campground (Reach 9, RM 14.8).

Of the four thermographs put out in 2003, only those placed below the private land and the one above Porter landing were recovered. The thermograph placed above the private land was found out of water. The approximate time it came out of the water was estimated.

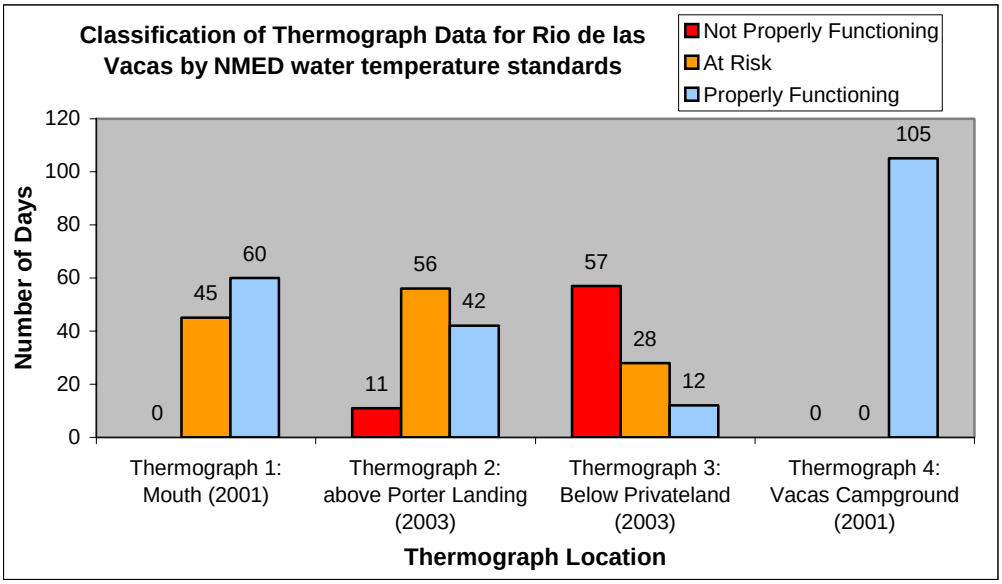
**Figure 27**. A comparison of not properly functioning, at risk, and properly functioning days at four thermograph sites in Rio de las Vacas. Sites recording in 2001 collected data between June 15th and September 30th. Sites recording in 2003 collected data between June 12th and September 30th. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on a seven-day average maximum.




When SFNF standards are applied, three out of the four stations were **not properly functioning** (see Figure 27). The Vacas Campground was the only section functioning **at risk**. The thermograph located below the private land in Reach 4 had the most not properly functioning days, indicating significant warming occurred above this site in the private land. The mouth had more not properly functioning days than the station two miles above it, but the measurements were taken in two different years. This could account for the variance.

Two stations recorded **not properly functioning** days when classified by NMED standards: above Porter Landing and Below Private Land (see Figure 28). The Mouth is functioning **at risk**. The Vacas Campground was the only **properly functioning** station.

**Figure 28**. A comparison of not properly functioning, at risk, and properly functioning days at four thermograph sites in Rio de las Vacas. Sites recording in 2001 collected data between June 15th and September 30th. Sites recording in 2003 collected data between June 12th and September 30th. Water temperature categories defined by NMED Water Quality Temperature Standards are based on a three-day average maximum.

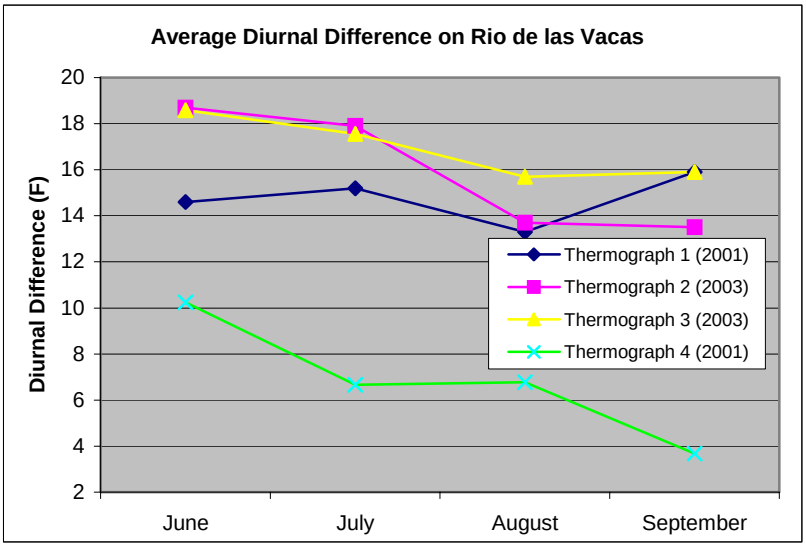



Looking at stream temperatures across elevation can distinguish areas in need of temperature mitigation. On a typical system, temperatures should increase as water flows downstream. Rio de las Vacas followed this pattern in 2001. On July 31st, 2001 stream temperatures ranged from 64.1°F near the Vacas Campground (elevation 8280') to 72.0°F near the mouth (elevation 7200'). In 2003, Rio de las Vacas did not follow the predicted pattern. On July 31st, 2003 temperatures ranged from 71.9°F at Thermograph Station 2 (elevation 7400') to 78.5°F at Thermograph Station 3 (elevation 7860'). This may be due in part to natural conditions (upwellings, coldwater springs, differing valley formations and aspect, etc.) although the inventory suggests that degraded conditions exist on the unsurveyed portion of private land, which have led to stream widening and shallowing which in turn has created elevated stream temperatures.

Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. On July 31st, 2003 thermograph station below private land had a diurnal difference of 20.9°F. The site above Porter Landing had a diurnal difference of 16.4°F. On the same day in 2001, the thermograph station at the mouth of Rio de las Vacas recorded a diurnal difference of 13.4°F. The station at the Vacas campground had a diurnal difference of 4.6°F. Diurnal difference averaged by month revealed similar trends (see Figure 29). The station at the Vacas campground had the lowest diurnal differences across both years. Thermograph Stations 2 and 3 had similar diurnal differences until August when Thermograph Station 2's diurnal differences dropped.

The **at risk** and **not properly functioning** classification of multiple sites by both Forest and NMED water quality standards and the break in the relationship between temperature and elevation in 2003 implies that water temperature should be a management consideration for Rio de las Vacas. Temperature mitigating strategies should be applied to protect the integrity of the cold-water fishery.

**Figure 29**. Diurnal difference averaged by month for the 4 thermograph stations on the Rio de las Vacas.




A survey conducted in 2001- 2003 found Rio de las Vacas to be heavily impacted by both dispersed recreation and grazing. To increase bank stability and streamside shade, surveyors recommended planting native species such as willow, aspen, and cottonwood in the riparian. Grazing practices should also be managed to protect the riparian. Options include using a range rider, riparian exclosures, or rotational grazing that minimizes grazing in the growing season. They also recommended limiting the use of dispersed trails and campsites through location, designation, and/or regulations (USDA Forest Service 2004(a)). A program called Respect the Rio has been implemented to limit the impact of dispersed camping on the river in the most heavily impacted corridor. This program involves regulating dispersed camping and educating campers. In addition, new riparian fencing was created to limit cattle and vehicle use. A stream and floodplain restoration project was completed between Thermograph Stations 1 and 2 in 2004. For more information on this project's methods and goals, please refer to the Respect the Rio Annual Report 2003 and 2004 (USDA Forest Service).

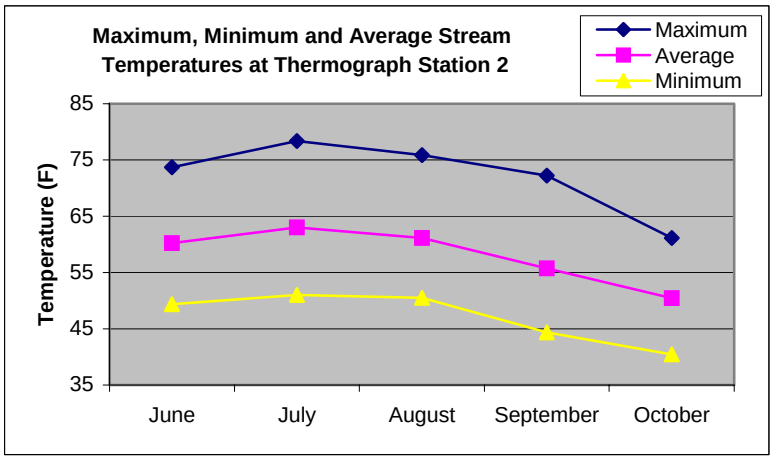
*Thermograph Station 1*: Mouth
*Elevation*: 7200'
*Stream Mile*: 0.0

**Photo 14**. Rio de las Vacas mouth (on left) near where Thermograph 1 was placed (04-Jul-01).

**Photo 15**. Looking downstream from thermograph location (12-Jun-03).

Average monthly diurnal difference peaked in June at 18.7°F (see Figure 29). The maximum daily diurnal difference observed was 26.2°F on July 10th. The minimum daily diurnal difference of 2.8°F was recorded on September 10th.

**Figure 31**. Maximum, minimum and average temperatures for each month at the thermograph station above Porter Landing.



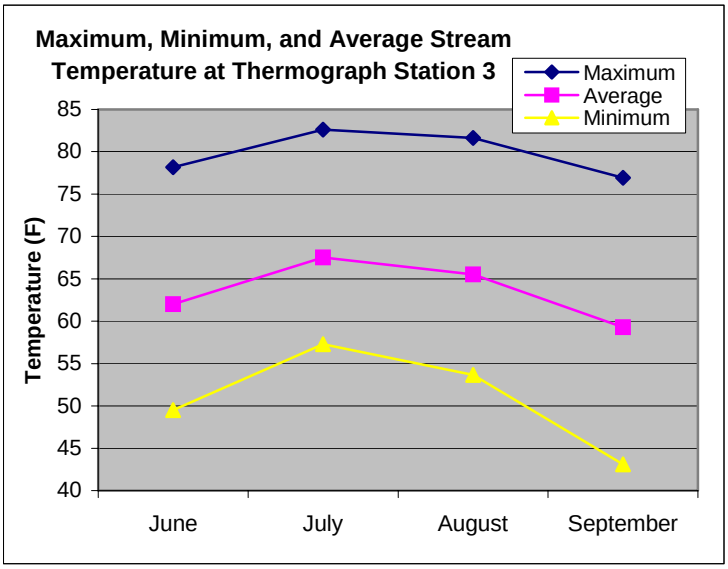

*Thermograph Station 3*: Below private land
*Elevation*: 7860'
*Stream Mile*: 9.6

Thermograph Station 3 monitored 15.0 miles of stream in 2002. This section of Rio de las Vacas primarily monitored the affect of an approximately 0.6-mile stretch of private land just above the thermograph site. Thermograph data collected in 2003 determined Rio de las Vacas below the private land boundary in Reach 6 was **not properly functioning** by both SFNF and NMED standards. Seventy-eight (78) days were not properly functioning (83.9% of days) by SFNF standards and 15 days were at risk (16.1% of days) out of 93 days. No properly functioning days were recorded. By NMED standards, 57 days were not properly functioning (58.8% of days) and 28 days were at risk (28.9% of days) out of 97 total days. Only 12 days were properly functioning (12.4% of days).

**Photo 16.** Slumping Banks and lack of riparian shade at the third thermograph station. G. Sausen standing where thermograph was deployed (12-Jun-03).

Maximum stream temperatures were recorded in July (see Figure 32). The peak temperature of 82.6°F was recorded on July 11th. Temperatures decreased steadily through September when the thermograph came out of the water.

**Figure 32**. Maximum, minimum and average temperatures for each month for the thermograph station located Below Private land.




Average monthly diurnal difference peaked in June at 18.6°F (see Figure 29). The maximum daily diurnal difference of 31.3°F was recorded on June 23rd. The minimum daily diurnal difference of 7.8°F was observed on August 2nd.

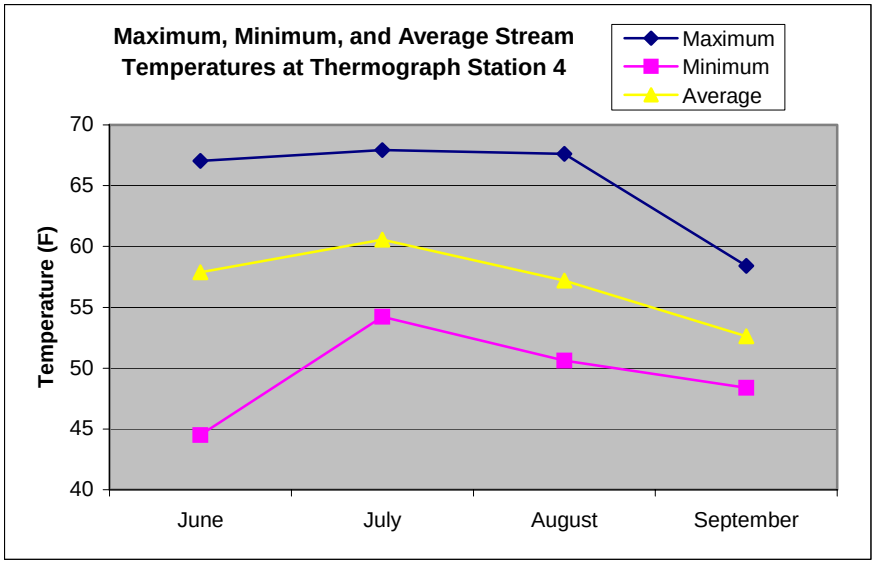
*Thermograph Station 4*: above Vacas Campground
*Elevation*: 8280'
*Stream Mile*: 14.8

Thermograph Station 4 monitored 9.9 miles stream miles in 2001. This section of Rio de las Vacas flows through a tight canyon and then enters the San Pedro Parks Wilderness where it passes through a series of open meadows. Thermograph data collected in 2001 above the Vacas Campground identified this station as **at risk** by SFNF standards. Twenty-one (21) days were at risk (20% of days) out of 105 total days. By NMED standards the station was **properly functioning** for all the days monitored.

**Photo 17.** Typical habitat above Rio las Vacas Campground where Thermograph 4 was placed (05-Sep-01).

Maximum stream temperatures at this station were very similar in June, July and August (see Figure 33). The peak temperature was 67.9°F on July 26th. Temperatures dropped steeply in September.

**Figure 33**. Maximum, minimum and average temperatures for the thermograph station at the Vacas Campground.



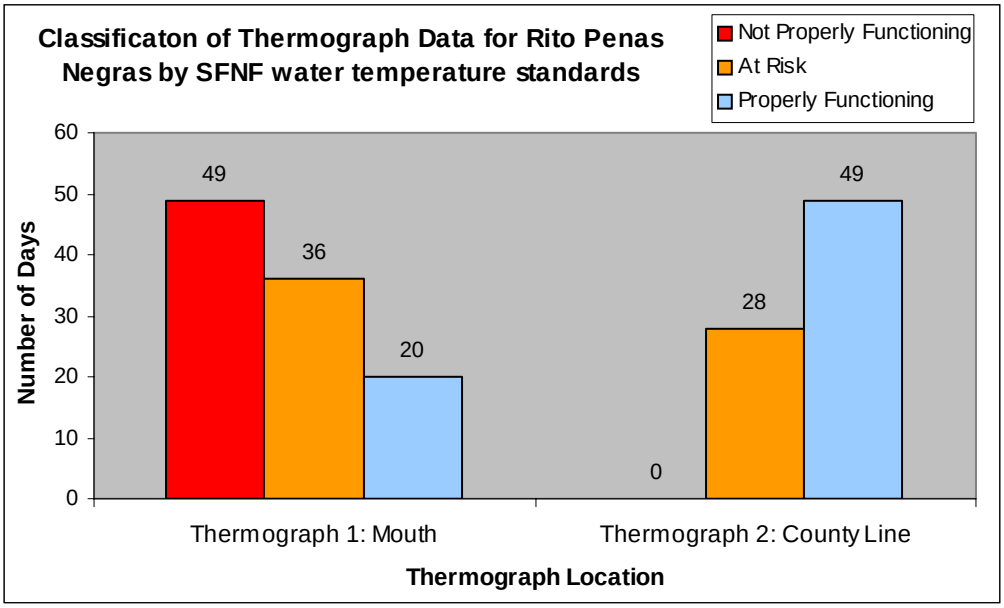
Average monthly diurnal difference peaked in June at 10.2°F (see Figure 29). The maximum daily diurnal difference of 13.8°F was recorded on June 19th. The minimum daily diurnal difference of 1.7°F occurred on September 13th.

## *Rito Peñas Negras*

Two temperature monitoring stations were established on Rito Peñas Negras (see Figure 18). The stations were not moved for the duration of the monitoring period. Thermographs recorded temperatures at 4-hour intervals. The first station was put placed near the mouth of the creek (River Mile 0.3). This thermograph recorded temperatures from June 12th through October 23rd, 2003. The second station was placed near the Sandoval/ Rio Arriba County Line (RM 6.6). This station recorded temperatures from July 10th through October 23rd, 2003.

Thermograph data collected between June 12th and September 30th, 2003 was used to determine water quality. When SFNF standards are applied Thermograph Station 2 was **at risk** and Thermograph Station 1 was **not properly functioning** (see Figure 34). Thermograph Station 2 had more properly functioning days than at risk days. Thermograph Station 1 had more days not properly functioning than properly functioning.

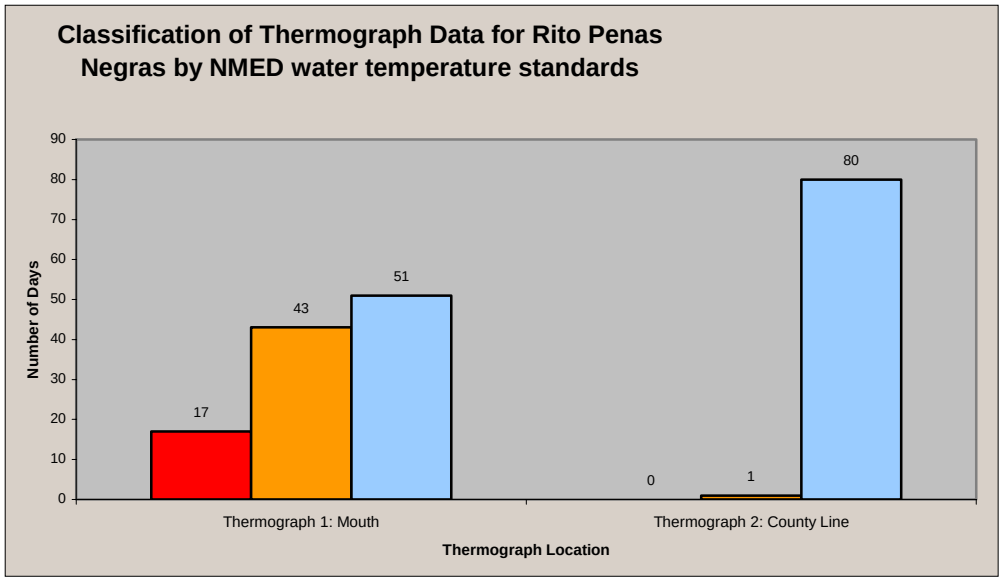
**Figure 34**. A comparison of not properly functioning, at risk, and properly functioning days two thermograph sites on Peñas Negras between June 12th and September 30th, 2002. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on a seven-day average maximum.




Thermograph Station 2 was also **at risk** days when NMED standards were applied. Thermograph Station 1was again classified as **not properly functioning** (see Figure 35). The number of at risk days at the Thermograph Station 2 was significantly less than the number of properly functioning days. Thermograph Station 1 had more properly functioning days than not properly functioning days and at risk days combined.

Looking at stream temperature across elevation can distinguish areas in need of temperature mitigation. On a typical system, temperature should increase as elevation decreases. Rito Peñas Negras does follow this pattern. On July 31st, maximum temperatures varied from 67.6°F at Thermograph Station 2 (elevation 8600') to 74.8°F at Thermograph Station 1 (elevation 8000'). This may be due to natural conditions (upwellings, coldwater springs, differing valley formations and aspect, etc.). A stream inventory is scheduled to begin in 2005 to locate sources for thermal variation.

**Figure 35**. A comparison of **not properly functioning**, **at risk**, and **properly functioning** days two thermograph sites on Peñas Negras between June 12th and September 30th, 2002. Water temperature categories defined by NMED Water Quality Temperature Standards are based on a three-day average maximum.



*Thermograph Station 1*: Mouth
*Elevation*: 8000'
*Stream Mile*: 0.3

Thermograph Station 1 monitored 6.3 stream miles. This section of Rito Peñas Negras passes through an open meadow system primarily managed by the Forest Service. Thermograph data collected in 2003 determined Rito Peñas Negras at the mouth is **not properly functioning**. By SFNF standards it was not properly functioning 49 days (46.7% of days) and at risk 36 days (34.3 % of days) out of 105 days. By NMED standards the station was not properly functioning 17 days (15.6% of days) and at risk 43 days (39.4% of days) out of 109 total days.

Maximum stream temperatures were recorded in July (see Figure 37). Temperatures peaked at 79.5°F on July 3rd, 2003. Stream temperatures then decreased steadily until the thermograph was pulled in October.

Average monthly diurnal difference peaked in July (see Figure 36). The maximum daily diurnal difference of 34.6°F was observed on July 9th. The minimum daily diurnal difference of 3.6°F occurred on October 3rd

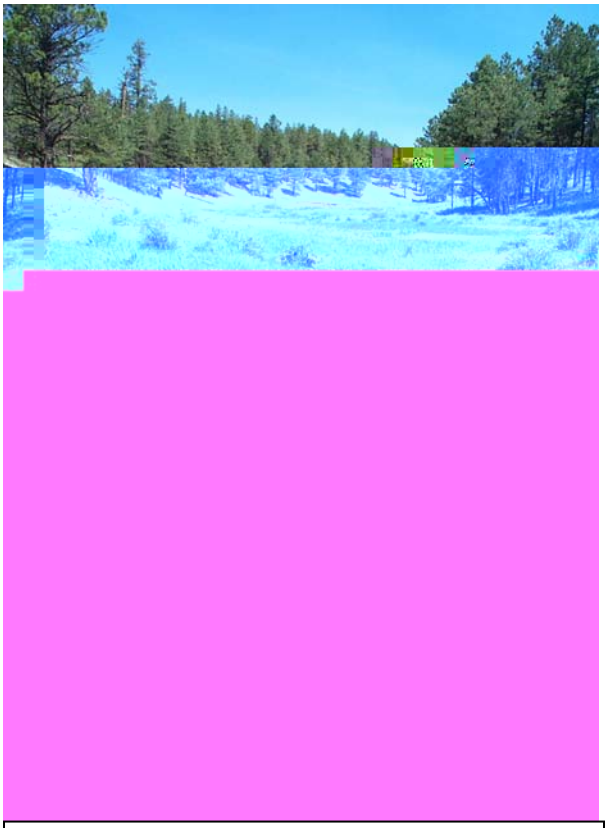
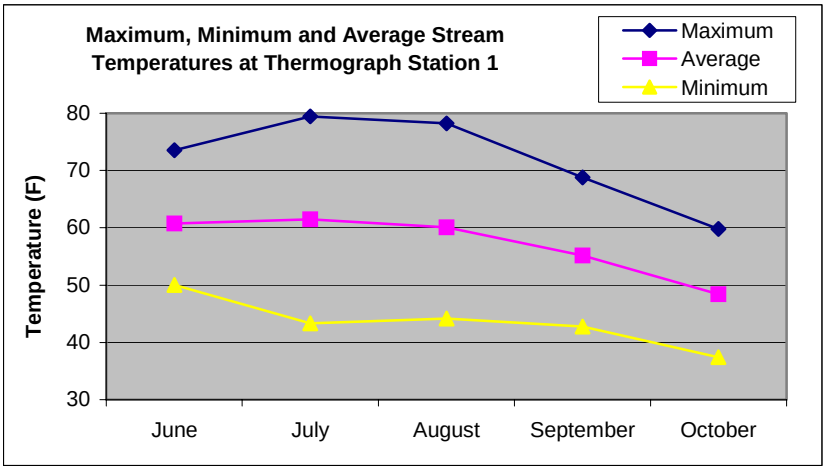


**Photo 18**. Open meadow near the mouth of Rito Peñas Negras. G. Sausen putting thermograph in pool (12-Jun-03).

**Figure 37**. Maximum, minimum and average temperatures for each month for the thermograph station at the Mouth.



*Thermograph Station 2*: County Line
*Elevation*: 8600'
*Stream Mile*: 6.6

Thermograph Station 2 monitored 5.2 stream miles. The thermograph only monitors a short stretch of Rito Peñas Negras (less than ¼-mile). Most of the stream miles monitored belongs to Rito Café. This section of stream is managed by Forest Service and private landowners. The stream flows primarily through an open canyon. Thermograph data collected in 2003 determined Rito Peñas Negras at the county line was **at risk**. By NMED standards it had 1 day at risk out of 81 days (1.2% of total days). SFNF standards classified 28 days out of 77 at risk (36.4% of days).

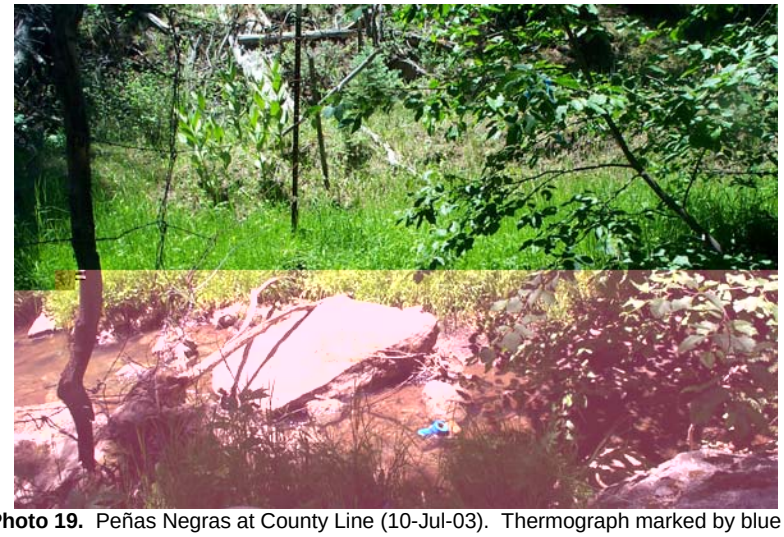
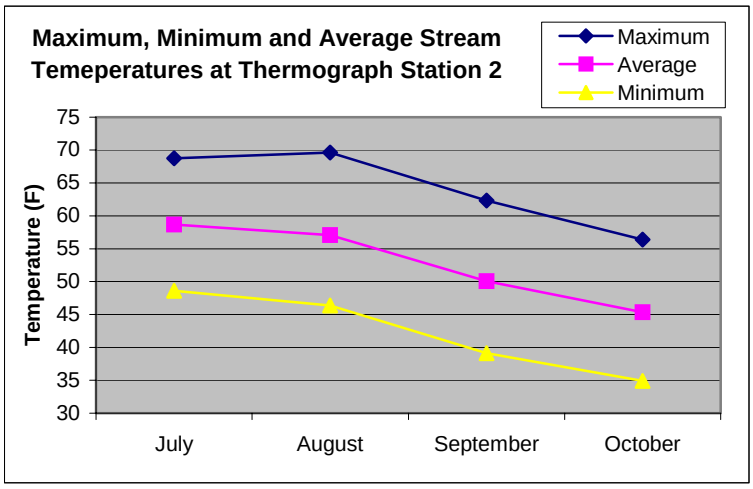


**Photo 19.** Peñas Negras at County Line (10-Jul-03). Thermograph marked by blue flagging.

Maximum stream temperatures were recorded in August (see Figure 38). Temperature peaked at 69.6°F on August 3rd, 2003. After August, temperatures decreased steadily until the thermograph was pulled in October.

**Figure 38**. Maximum, minimum and average temperatures for each month for the thermograph station at the County Line.



Average monthly diurnal difference peaked in July and again in September (see Figure 36). The maximum daily temperature fluctuation of 16.8°F occurred on August 3rd. The minimum daily diurnal difference of 3.9°F was recorded on October 2nd.

## *A Tributary to Rito Café*

One temperature monitoring station was established on a tributary to Rito Café (see Figure 18) . The station was not moved during the monitoring period. The station was located just off of Forest Road 70 (River Mile 0.2). This thermograph monitored 1.1 miles of stream. Stream temperatures were recorded from July 10th through October 23rd, 2003. The thermograph recorded temperatures at 4-hour intervals.

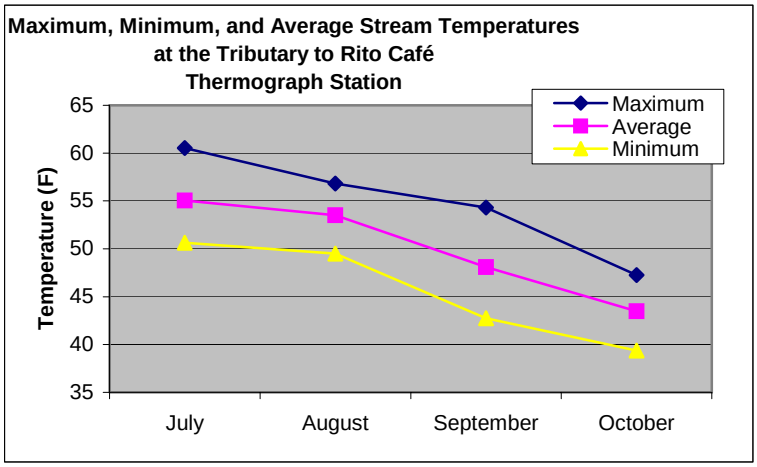
Thermograph data collected between July 10th and September 30th was used to determine water quality. When SFNF and NMED standards were applied the tributary was classified as **properly functioning**. It had no not properly functioning or at risk days by either standard (see Figure 39 and Figure 40).

The properly functioning classification by both SFNF and NMED water quality standards means this stream can support a healthy coldwater fishery. This system should be maintained in its current state. A stream inventory is scheduled to begin in 2005 to identify any threats to maintaining proper stream function.

**Photo 20.** Thermograph placed in typical narrow pool in Rito Café (10-Jul-03). Thermograph lh l

Maximum stream temperatures were recorded in July (see Figure 41). Temperatures peaked at 60.5°F on July 11th, 2003. Temperatures declined steadily through October until the thermograph was pulled.

**Figure 41**. Maximum, minimum and average temperatures for each month for the thermograph station on a tributary to Rito Café.




Average monthly diurnal difference peaked in July and also in September (see Figure 42). Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. The maximum daily diurnal difference of 9.3°F was recorded on July 17th. The minimum daily diurnal difference of 1.1°F occurred on August 29th.

**Figure 42.** Diurnal difference averaged by month for the thermograph station on the tributary to Rito Café.

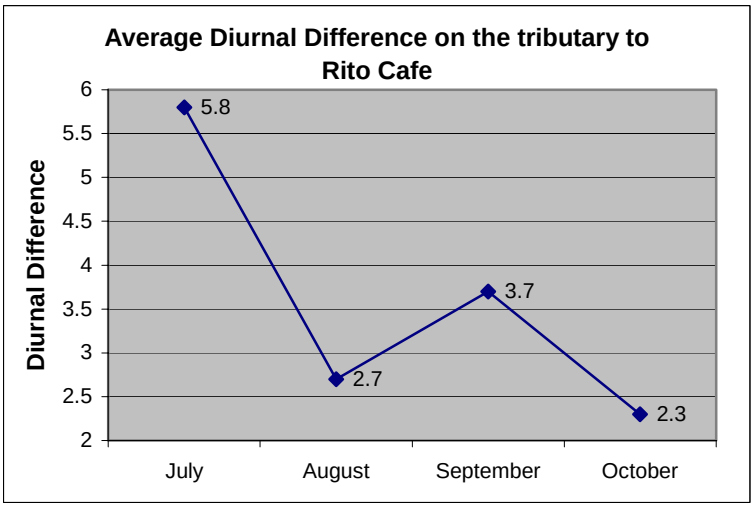
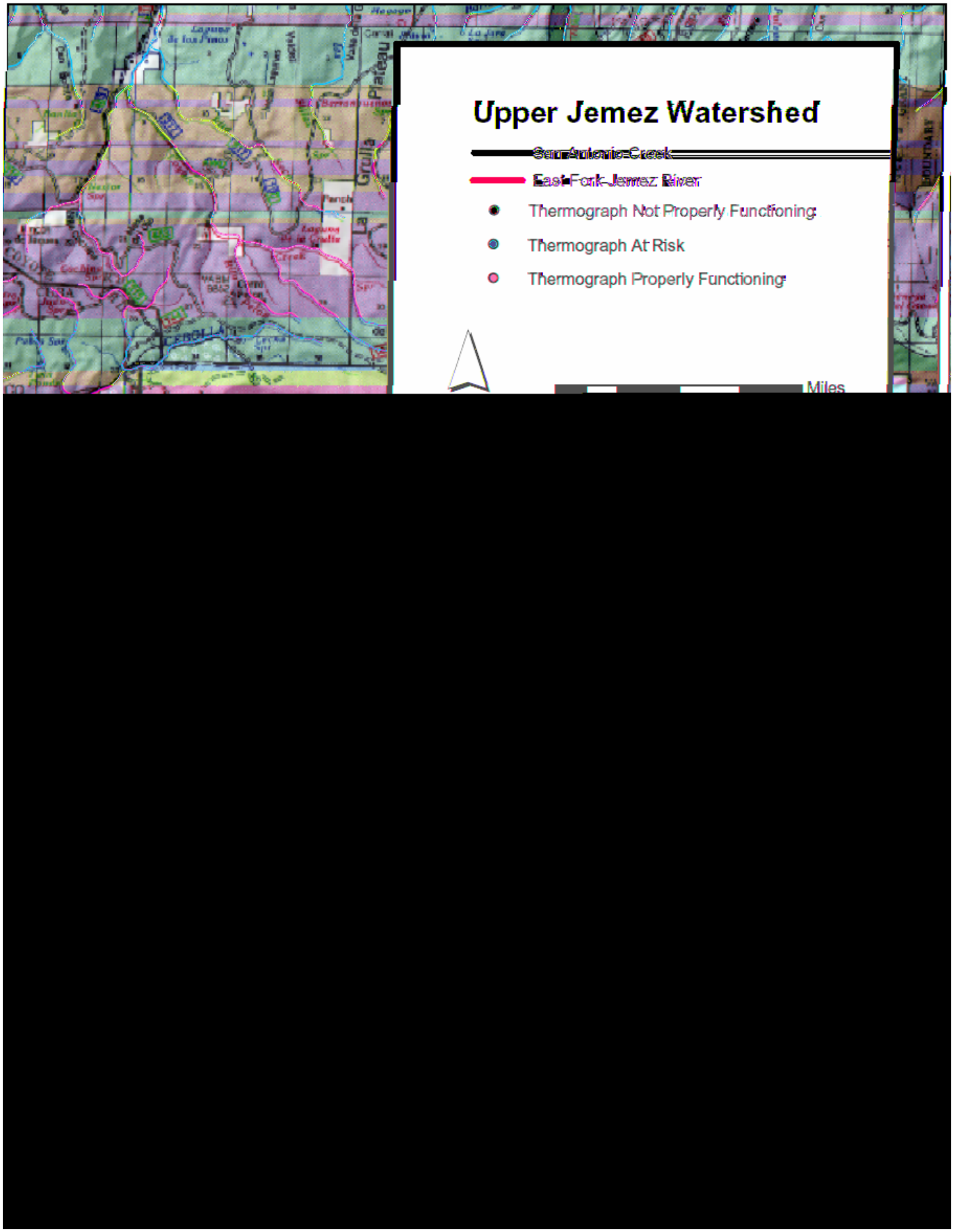


Figure 43. Map of thermograph locations in Upper Jemez Watershed. Stream temperature classifications are based on SFNF standards.



# Upper Jemez Watershed

The Upper Jemez Watershed is located on the southern flank of the Jemez Mountains and is managed by Jemez Ranger District, private landowners, and Valles Caldera National Preserve. Streams flow mostly east to west and eventually flow into the Jemez River. The watershed's management is guided by special designation as a Wild and Scenic River, National Recreation Area, and Santa Fe National Forest Land and Resource Management Plan. The watershed has been listed as impaired under Section 303(d) of the Clean Water Act by New Mexico Environment Department. The impairments include turbidity, stream bottom deposits, temperature, acute aluminum, pH, and conductivity (NMED 2003).

Recent stream surveys noted a lack of pool development, increased fines in riffle habitat, lack of large woody debris, and degraded riparian condition. Management activities in the watershed that may be affecting stream temperature include grazing, road construction in the floodplain, historic logging activities, fuel wood removal, and recreational activities including camping in developed and dispersed sites, hiking, and fishing (USDA Forest Service 2002, USDA Forest Service 2003(e)).

**Table 5.** Summary of data collected in Upper Jemez Watershed

| River | Year Monitored | River Miles Monitored | # of thermo-graphs | NMED | | | SFNF Standards | | | Districts |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | NF | AR | PF | NF | AR | PF | |
| East Fork Jemez | 2001 | 21.4 | 2 | 2 | 0 | 0 | 2 | 0 | 0 | Jemez RD |
| San Antonio | 2002 | 30.5 | 5 | 4 | 1 | 0 | 4 | 1 | 0 | Jemez RD |

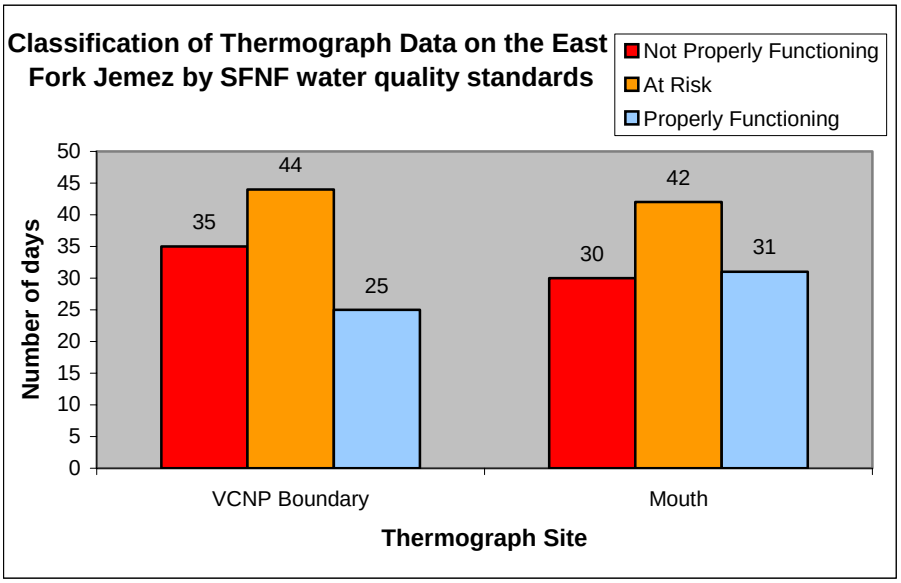
(NF= not properly functioning, AR= at risk, PF= properly functioning).

## *East Fork Jemez River*

Two temperature monitoring stations were established on East Fork Jemez (see map page 52). The stations were not moved for the duration of the monitoring period. Temperatures were recorded from June 13th through October 3rd, 2001. Thermographs recorded temperatures at 4-hour intervals. The first thermograph was placed in Reach 1 of the 2001 survey at Battleship Rock Picnic Area near the mouth of the creek (River Mile 0). The second thermograph was placed in Reach 6 near the VCNP boundary (RM 10.4).

Thermograph data collected between June 13th and September 30th was used to determine water quality. When SFNF standards are applied, both stations were **not properly functioning** (see Figure 44). The VCNP site had more not properly functioning days than properly functioning days. Both sites also had more at risk days than properly functioning days.

**Figure 44**. A comparison of not properly functioning, at risk, and properly functioning days at two thermograph sites in East Fork Jemez Creek between June 13th and September 30th, 2002. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on a seven-day average maximum.

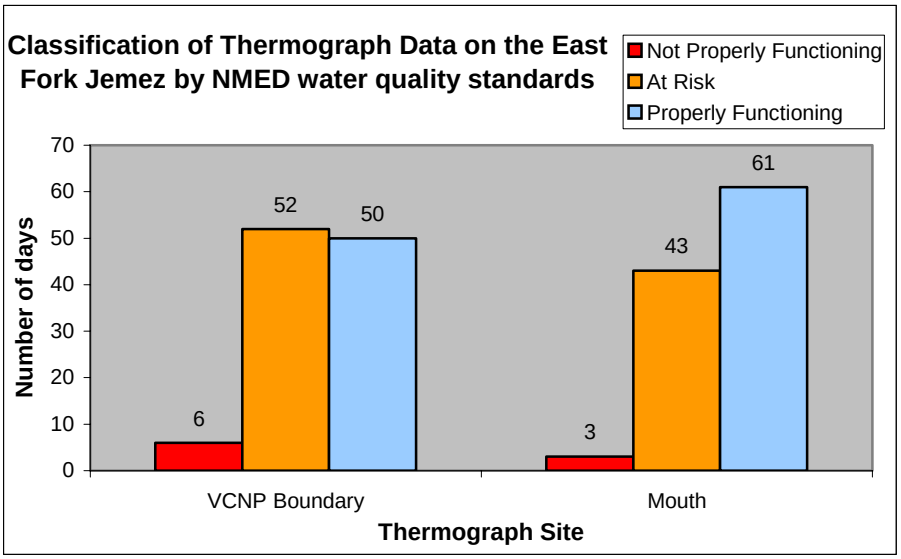



The two thermograph stations were also **not properly functioning** by NMED standards (see Figure 45). Both sites had significantly more at risk days than not properly functioning days. They also had more properly functioning days than not properly functioning days.

Looking at stream temperatures across elevation can also distinguish areas in need of temperature mitigation. On a typical system, temperatures should increase as elevation decreases. East Fork Jemez does not follow this pattern. On July 31st, maximum temperatures varied from 72.4°F at Thermograph Station 1 (elevation 6800') to 74°F at Thermograph Station 2 (8460'). This may be due in part to natural conditions (upwellings, coldwater springs, differing valley formations and aspect, etc.) although the inventory suggests that degraded conditions in Valle Grande have led to stream widening and shallowing which in turn has created elevated stream temperatures despite the high elevation (USDA Forest Service 2002).

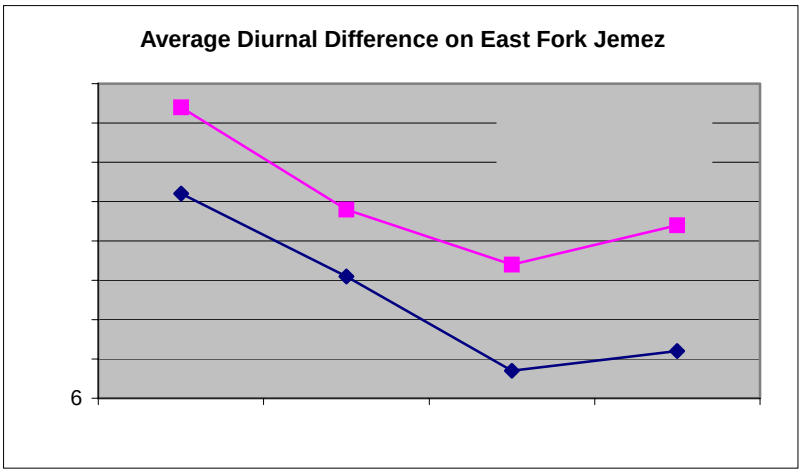
Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. On July 31st, diurnal difference ranged from 12.1°F at the VCNP boundary to 7.3°F at the mouth. Throughout the summer the diurnal difference was higher for the thermograph station at the VCNP boundary (see Figure 46). As the stream flows through Forest Service land the temperatures fluctuate much less.

**Figure 45**. A comparison of not properly functioning, at risk, and properly functioning days at two thermograph sites in East Fork Jemez Creek between June 13th and September 30th, 2002. Water temperature categories defined by NMED Water Quality Temperature Standards are based on a three-day average maximum.




The **not properly functioning** classification of both sites by NMED and SFNF water quality standards and the break in the relationship between temperature and elevation implies water temperature should be a management consideration for East Fork Jemez. Temperature mitigating strategies should be applied to protect the integrity of the cold-water fishery.

**Figure 46**. Diurnal difference averaged by month for two thermograph stations on East Fork Jemez.



methods and goals, please refer to the Respect the Rio Annual Report 2003 and 2004 (USDA Forest Service).

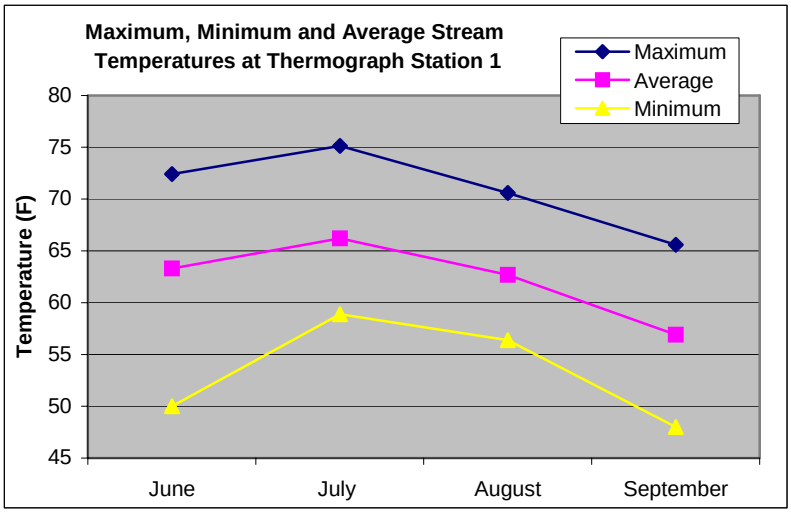
*Thermograph Station 1*: Mouth
*Elevation*: 6800'
*Stream Mile*: 0.0

Thermograph Station 1 monitored 10.4 stream miles. This section of East Fork Jemez River flows through a narrow canyon. Forest Service Trail 137 parallels the river for most of its length. The lower half of this reach sees the most human use. At the mouth is a developed picnic area (Battleship Rock) and near the middle is Jemez Falls Campground. Thermograph data collected in 2001 determine the mouth of East Fork Jemez was **not properly functioning** by both NMED and SFNF standards. NMED standards established 3 not properly functioning days (2.8% of days), and 43 at risk days (40.2% of days) out of 107 total days. Thirty (30) days were not properly functioning (29.1% of days) and 42 days were at risk (40.8% of days) out of 103 days by SFNF standards.

**Photo 21**. Typical riffle near the mouth of the East Fork Jemez (02-Nov-01).

Maximum stream temperatures were recorded in July (see Figure 47). Stream temperature peaked at 75.1°F on July 7th. Temperatures decreased through September. The thermograph was removed in early October.

**Figure 47**. Maximum, minimum and average temperatures for each month for the thermograph station at the Mouth.




Average monthly diurnal difference peaked in June (see Figure 46). The maximum daily temperature fluctuation of 15.4°F occurred on June 16th. The minimum diurnal difference of 7.2°F was recorded on June 26th.

*Thermograph Station 2*: VCNP boundary
Elevation: 8460'
Stream Mile: 10.4

Thermograph Station 2 monitored 8.7 stream miles. This section of East Fork Jemez River flows through the open meadows of the Valles Caldera (VCNP) to the stream's headwaters. Thermograph data collected in 2001 determined East Fork Jemez at the VCNP boundary was **not properly functioning** by both NMED and SFNF water quality standards. By NMED standards 6 days were classified as not properly functioning (5.6% of days) and 52 days were at risk (48.1% of days) out of 108 days. SFNF standards classified 35 days as not properly functioning (33.7% of days) and 44 days as at risk (42.3% of days) out of 104.

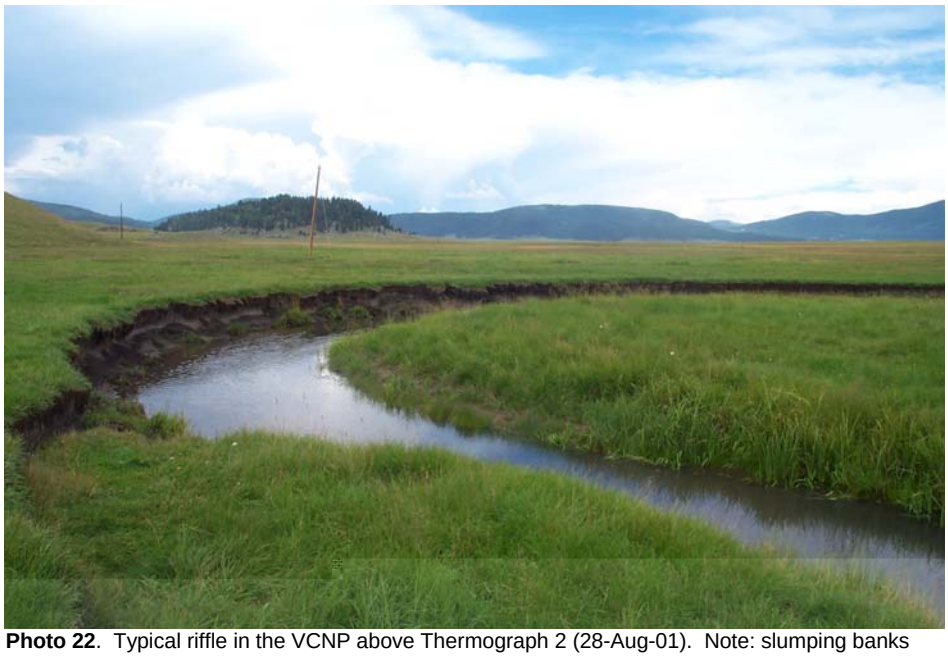
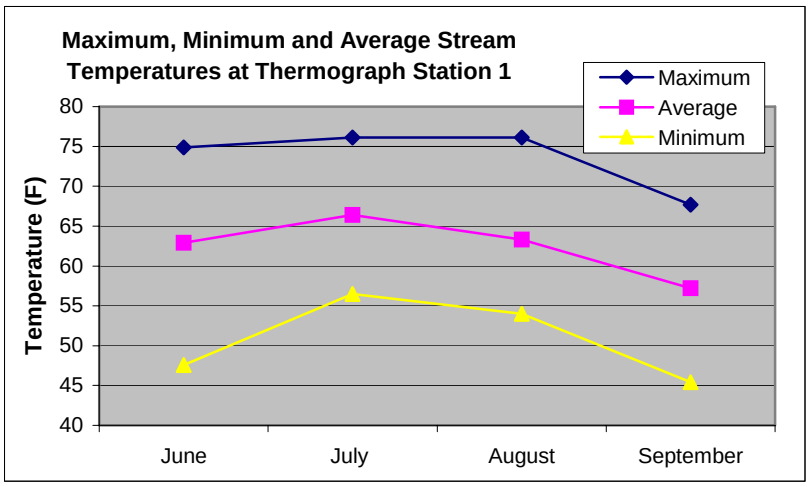


**Photo 22**. Typical riffle in the VCNP above Thermograph 2 (28-Aug-01). Note: slumping banks and widened stream channel.

Maximum temperatures were recorded in July and August (see Figure 48). Temperatures peaked at 76.1°F on July 4th and August 1st. In September temperatures decreased sharply. The thermograph was pulled in early October.

**Figure 48.** Maximum, minimum and average temperatures for each month for the thermograph station at the VCNP Boundary.



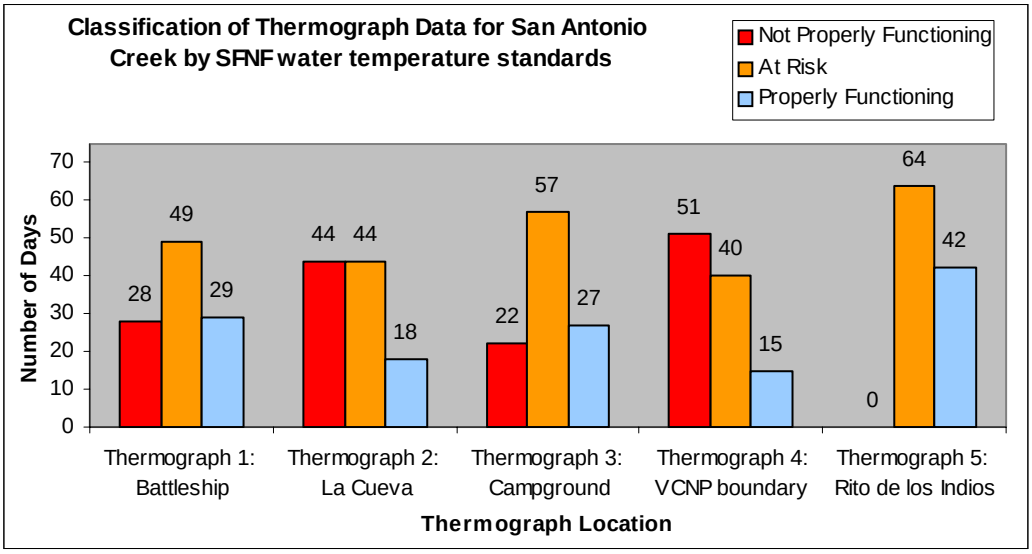

Average monthly diurnal difference peaked in June (see Figure 46). The maximum daily diurnal difference of 19.4°F occurred on June 16th. The minimum daily diurnal difference of 2.5°F was recorded on August 31st.

## *San Antonio Creek*

Five temperature monitoring stations were established on San Antonio Creek (see Figure 43). The stations were not moved for the duration of the monitoring period. Water temperature was recorded between June 11th and November 24th, 2002. Thermographs recorded temperatures at four-hour intervals. The first station was placed at the mouth of San Antonio Creek, just above the confluence with East Fork Jemez River (Reach 1, River Mile 0.0). Upstream, Thermograph Station 2 was located behind La Cueva Lodge near the junction of Highway 4 and 126 (Reach 2, RM 3.8). This station was placed immediately downstream from a section of private land. Thermograph Station 3 was located at San Antonio Campground off Highway 126, shortly upstream from the private land (Reach 4, RM 5.3). Thermograph Station 4 was located at the VCNP boundary (Reach 7, RM 12.1). The final station was placed immediately downstream of Rito de los Indios confluence near the headwaters of San Antonio Creek on the VCNP (Reach 8, RM 25.3).

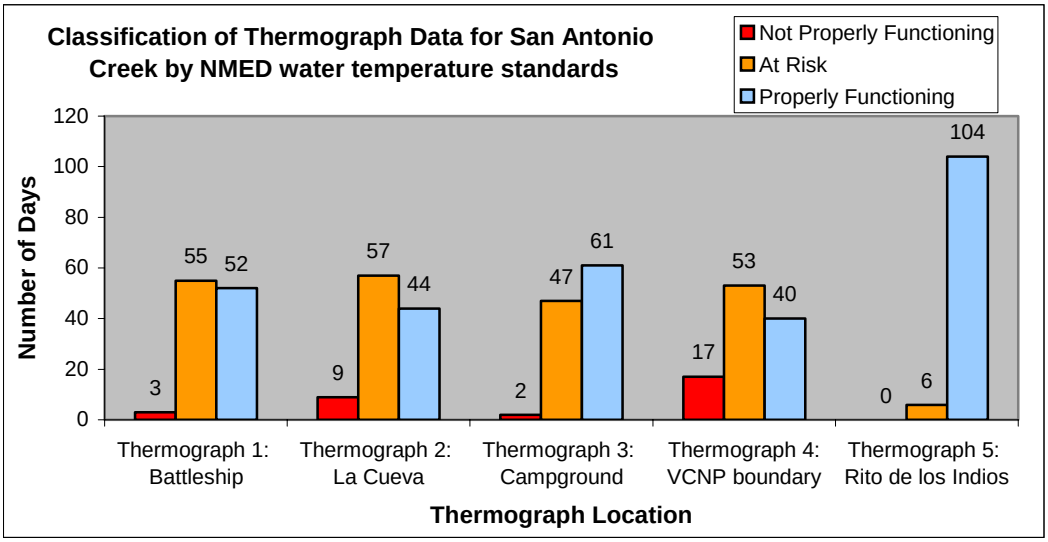
When Forest standards are applied to the collected temperature data, four out of the five stations were **not properly functioning** (see Figure 49). Thermograph Station 5 was the only section functioning **at risk**. The VCNP Boundary station had the most not properly functioning days, indicating significant warming occurred above this site in the Valles Caldera National Preserve (VCNP). Not properly functioning days then decreased to the Campground station as the river passed through Forest land. Temperatures again increase at the La Cueva Station as the river passes through private land. Finally, temperatures decrease at the Battleship station, again on Forest land.

**Figure 49.** A comparison of not properly functioning, at risk, and properly functioning days at five thermograph sites in San Antonio Creek between June 11th and September 30th, 2002. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on a seven-day average maximum.



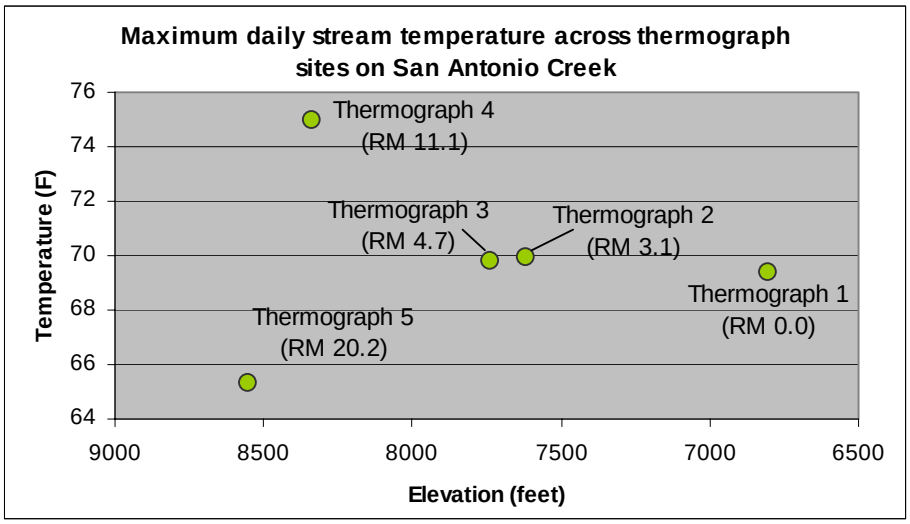

Four stations recorded **not properly functioning** days when classified by NMED standards: Thermograph Station 1 to 4 (see Figure 50). Thermograph Station 5 was **at risk**. Under both Forest and NMED standards, the VCNP Boundary and La Cueva stations exceeded not properly functioning standards the most of the five stations.

**Figure 50.** Comparison of days not properly functioning, at risk, and properly functioning at five thermograph sites in San Antonio Creek between June 11th and September 30th, 2002. Water temperature categories defined by NMED Water Quality Temperature Standards are based on three-day average maximum.



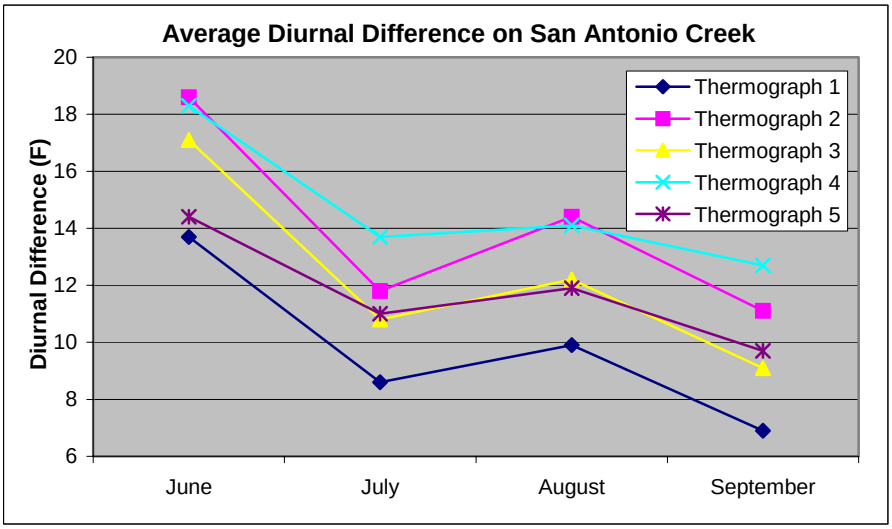

Looking at stream temperature across elevation can distinguish areas in need of temperature mitigation. On a typical system temperatures should increase as elevation decreases. San Antonio Creek does not follow this pattern (see Figure 51). On July 19th, Thermograph Station 4 (elevation 8340') recorded the highest temperature at 75.0°F. This station should have exhibited lower temperatures than the three previous stations. Thermograph Station 1 (elevation 6800') which should have had the highest temperature actually recorded temperatures lower than Thermograph Stations 2, 3 and 4.

**Figure 51.** Maximum stream temperatures on July 31st, 2002 across five thermograph stations on San Antonio Creek.




Diurnal or daily temperature fluctuations were analyzed from the thermograph stations. Diurnal difference is a measure of daily stream fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. On July 19th, 2002, a particularly warm day, diurnal fluctuations ranged from 13.1 F at the Battleship station to 18.4 F at La Cueva. Thermograph Stations 2 and 4 consistently had higher diurnal differences than the other three stations (see Figure 52). Thermograph Station 1 had the smallest daily temperature fluctuations.

**Figure 52**. Diurnal difference averaged by month for five thermograph stations on San Antonio Creek.




Water temperature should be a management consideration for San Antonio Creek as indicated by the **at risk** and **not properly functioning** classification of all the sites by both NMED and SFNF water quality standards and the break in the relationship between temperature and elevation. Temperature mitigation strategies should be applied to protect the integrity of the coldwater fishery.

San Antonio Creek was surveyed in 2002. Surveyors identified many factors affecting stream temperatures at the five thermograph sites. Two main factors influence temperatures at the Rito de los Indios site. First, the station is located near the headwaters with little time for solar warming. In addition, fifteen tributaries enter San Antonio Creek between the headwaters and Rito de los Indios. Many of these tributaries are springs, which moderate stream temperatures during hot summer months (USDA Forest Service 2003(e)).

Factors affecting the increasing temperatures between Rito de los Indios and the VCNP Boundary stations are solar warming, stream widening caused by bank instability, valley morphology and tributaries. The highly sinuous and low gradient wide valley morphology between Rito de los Indios creates an opportunity for solar warming. Solar warming is compounded by the lack of shade provided by riparian vegetation, collapsing undercut banks, and a wide and shallow channel shape. Several road crossings decrease stream depth and increase wetted width, exacerbating solar warming. Fifteen tributaries enter San Antonio Creek between the two stations. Two tributaries contribute more than an estimated 5% of the main channel flow and had properly functioning temperatures at the time of survey. Other tributaries ranged between PF and NPF temperatures with one hot spring. The hot spring contributed less than 5% of the flow at 100°F (13 Aug 2002 at 12:30).

Properly functioning days increases between the VCNP Boundary and the Campground under both the Forest and NMED standards (see Figures 49 and 50), but still remains **not properly functioning** under the Forest standard. Several factors contribute to the temperature decrease at the Campground station including a change in valley morphology, gradient and riparian vegetation. The valley morphology between the VCNP Boundary Station and the Campground Station becomes more confined allowing less solar contact. The riparian community shifts to include shade-providing vegetation and further decreases the sun's contact with San Antonio

Creek. Although temperatures generally decrease through this section, several natural and human-caused warming factors influence water temperatures between the VCNP Boundary and the Campground. Factors that increase water temperatures and affect this section of stream include San Antonio Hot Springs, high human use and its impacts, grazing and previous anthropogenic stream modifications. San Antonio Hot Springs increased local San Antonio Creek's water temperatures by 2 F as determined by grab temperature samples collected at the time of survey. Heavy recreational use in this area and at San Antonio Campground increase erosion and sediment inputs to San Antonio Creek, which also lead to increased water temperatures. Areas of stock grazing, which contribute to decreased bank stability, had collapsed undercut banks and decreased riparian vegetation. Aside from these warming influences, the overall stream temperature decreases between VCNP Boundary and the Campground stations.

Only 1.5 miles separate the La Cueva and Campground stations, but there is a significant increase in temperature, listing this section as **not properly functioning** for both standards. This section of river is entirely private except for a few hundred feet managed by Forest Service. Visual observations of land use and habitat measurements of San Antonio Creek noted heavy grazing, stream modifications, loss of woody vegetation, and unstable banks. Excessive grazing can have degrading effects on stream habitat resulting in increased stream temperatures. Stream modifications, unless performed properly, can also degrade stream habitat and increase temperatures.

Stream temperatures decrease over the last four miles to Battleship. The valley morphology becomes confined, minimizing solar radiation. There is some natural influence related to Spence Hot Springs. Stream temperatures would improve if upstream conditions were improved.

Surveyors recommended improving the riparian zone as a primary means of mitigating temperature. In particular they recommended augmenting current riparian density by planting native species, managing grazing practices to provide additional protection for the riparian zone between Highway 126 and the VCNP boundary fence, and reducing the number and limiting the use of dispersed trails and campsites in the riparian zone. In 2003, the San Antonio Hot Springs Area was converted to a "day use only" area (USDA Forest Service 2003(e)).

*Thermograph Station 1*: Battleship Rock
*Elevation:* 6800'
*Stream Mile:* 0.0

Thermograph Station 1 monitored 3.1 stream miles. This section of San Antonio Creek is paralleled by State Highway 4. It sees a large amount of recreation use and has several established picnic and fishing areas as well as Spence Hot Springs. Thermograph data collected in 2002 determined San Antonio Creek at Battleship Rock was **not properly functioning** by SFNF standards. Twenty-eight (28) days were not properly functioning (26.4% of days) out of 106. An additional 49 days were at risk (46.2% of days). By NMED standards the site was **not properly functioning**, exceeding state standards 3 days out of 110 (2.7% of days). The site was at risk 55 days (50.0% of days).

Maximum stream temperatures were recorded in July (see Figure 53). Stream temperatures peaked at 75.4°F on July 26th. Temperatures decreased steadily until the thermograph was pulled in December.

**Photo 23**. Mouth of San Antonio Creek where Thermograph 1 was deployed (26-Jun-02).

Diurnal difference was calculated for June through September. Average monthly diurnal difference peaked in June (see Figure 52). The maximum fluctuation in daily temperature of 17.4°F was observed on June 13th. The minimum diurnal difference of 2.3°F was recorded on September 11th.

**Figure 53**. Maximum, minimum, and average temperatures for each month for the thermograph station at the Mouth.

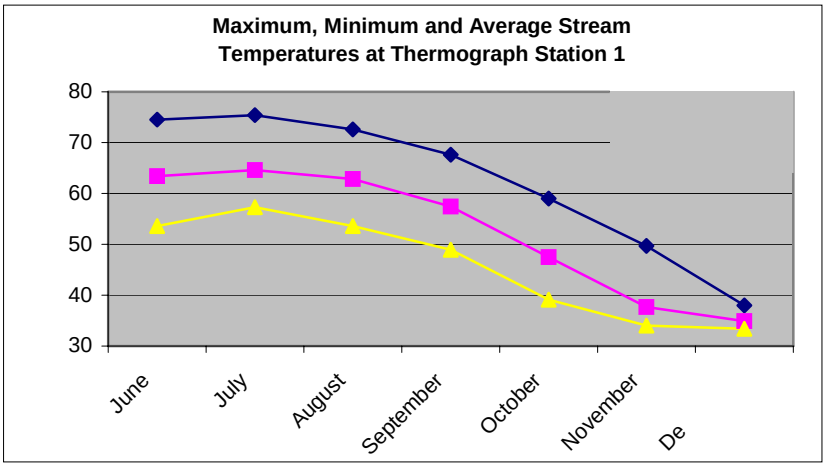
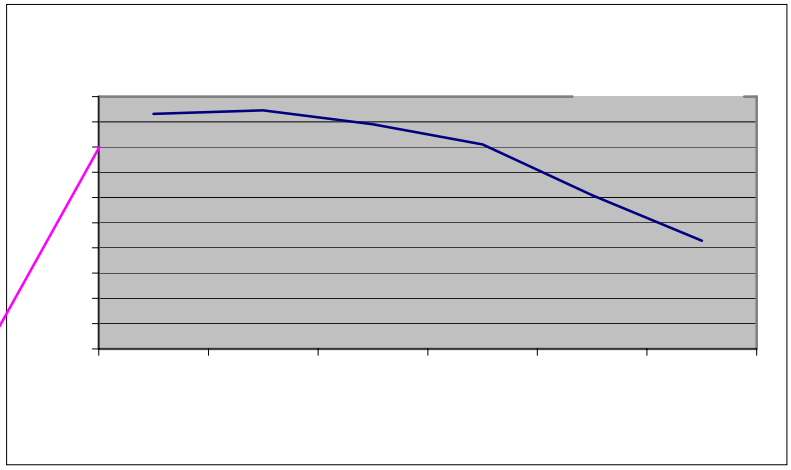


**Photo 24**. Beaver Pond behind La Cueva Lodge near where Thermograph 2 was deployed (17-Jul-02).

Maximum stream temperatures were recorded in July (see Figure 54). On July 26th, stream temperature peaked at 77.3°F. Temperatures decreased steadily until the thermograph was pulled in November.

**Figure 54**. Maximum, minimum, and average temperatures for each month for the thermograph station at La Cueva.

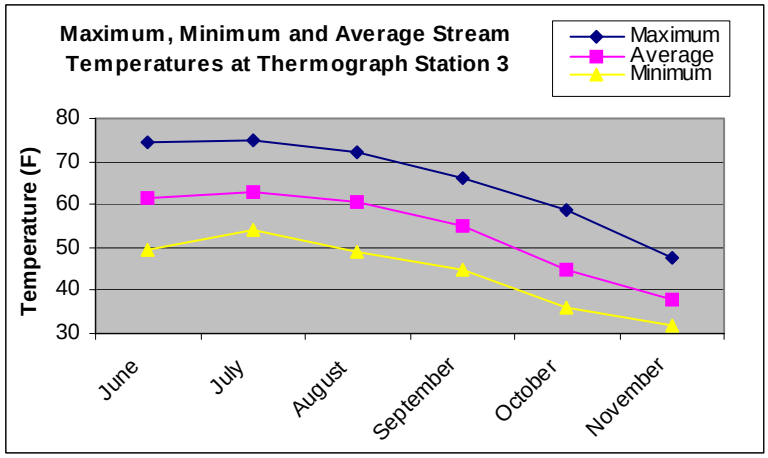


Springs. Thermograph data collected in 2002 determined San Antonio Creek near the campground was **not properly functioning** by both NMED and SFNF water quality standards. By SFNF standards 22 days were not properly functioning (20.8% of days) and 57 days were **at risk** (53.8% of days) out of 106. Two days were **not properly functioning** (1.8% of days) by NMED standards and 47 days were **at risk** (42.7% of days) out of 110 days.

**Photo 25**. Riffle habitat along San Antonio Campground near Thermograph Station 3 (22-Jul-02).

Maximum stream temperatures were recorded in July (see Figure 55). Stream temperature peaked at 74.9°F on July 25th. Temperatures decreased steadily until the thermograph was pulled in November.

**Figure 55.** Maximum, minimum, and average temperatures for each month at the thermograph station located at San Antonio Campground.




Diurnal difference was calculated for June through September. Average monthly diurnal difference peaked in June (see Figure 52). The maximum daily temperature fluctuation of 21.9°F occurred on June 13th. The minimum daily diurnal difference of 1.7°F occurred on September 10th.

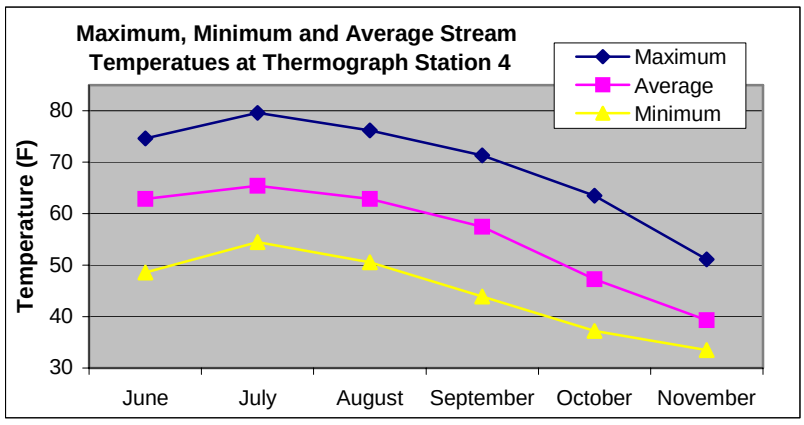
*Thermograph Station 4*: VCNP boundary
*Elevation*: 8340'
*Stream Mile*: 11.1

Thermograph Station 4 monitored 9 stream miles. This section of San Antonio Creek passes through the open meadows of the Valles Caldera Preserve. Thermograph data collected in 2002 determined San Antonio Creek at the Valles Caldera Boundary was **not properly functioning** by both NMED and SFNF water quality standards. The thermograph recorded 51 not properly functioning days (48.1% of days) and 40 at risk days (37.7% of days) out of 106 when compared to SFNF standards. Seventeen (17) not properly functioning days (15.5% of days) were recorded by NMED standards out of 110. An additional 53 days were at risk (48.2% of days).

**Photo 26**. Valles Caldera Boundary where Thermograph 4 was deployed (05-Aug-02).

Maximum stream temperatures were recorded in July (see Figure 56). Temperature peaked at 79.6°F on July 27th. Stream temperatures decreased steadily until the thermograph was pulled in November.

**Figure 56**. Maximum, minimum and average temperatures for each month for the thermograph station at the Valles Caldera Boundary.




Diurnal difference was calculated for June through September. Average monthly diurnal difference peaked in June (see Figure 52). The maximum daily temperature fluctuation of 25.7°F was recorded on June 13th. The minimum daily diurnal difference of 3.4°F occurred on September 10th.

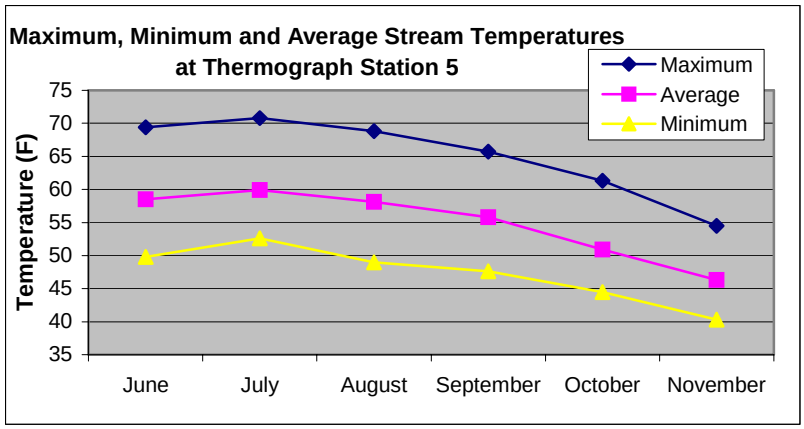
*Thermograph Station 5*: Confluence with Rito de los Indios
*Elevation*: 8550'
*Stream Mile*: 20.2

Thermograph Station 5 monitored seven stream miles. This section of San Antonio Creek flows through the open meadow system of the Valles Caldera Preserve and terminates at the headwaters of San Antonio Creek. Thermograph data collected in 2002 determined San Antonio Creek at the confluence with Rito de los Indios was **at risk** by both NMED and SFNF standards. Sixty-four (64) days were **at risk** (60.4% of days) out of 106 by SFNF standards. By NMED standards 6 days were **at risk** (5.5% of days) out of 110.

**Photo 27**. Typical open canopy over stream above where Thermograph 5 was deployed (22-Aug-02).

Maximum stream temperatures were recorded in July (Figure 57). Temperature peaked at 70.8°F on July 24th. Stream temperatures decreased steadily until the thermograph was pulled in November.

**Figure 57**. Maximum, minimum and average temperatures for each month for the thermograph station above the confluence with Rito de los Indios.




Diurnal difference was calculated for June through September (see Figure 52). The maximum daily temperature fluctuation of 19.3°F was recorded on June 18th. The minimum daily diurnal difference of 1.7°F occurred on September 10th.

# Pecos GMU

Cow Creek Watershed
Upper Gallinas Watershed
Pecos Headwaters Watershed

Pecos River Headwaters

Figure 58. Map of thermograph locations in Cow Creek Watershed. Stream temperature classifications are based on SFNF standards.

# Cow Creek Watershed

The Cow Creek Watershed is located eastside of the Sangre de Cristo Mountains and is managed by the Pecos/Las Vegas Ranger Districts and private landowners. Streams flow mostly north to south and eventually enter into the Pecos River. The watershed's management is guided by the Santa Fe National Forest Land and Resource Management Plan. The watershed has been listed as impaired under Section 303(d) of the Clean Water Act by New Mexico Environment Department. The impairments include stream bottom deposits (NMED 2003).

Recent stream surveys also noted increased fines in riffle habitat, lack of large woody debris, and lack of pool development. In 2000 a catastrophic fire called the Viveash Fire burned 83% of the upper Cow Creek Watershed. Forty-two (42) percent of this area experienced a high severity burn. Much of the habitat degradation in the Cow Creek Watershed can be attributed to the after affects of this fire that has increased sedimentation, mass erosion and turbidity in the system. Management activities that potentially confound these factors include grazing, road construction in the floodplain, historic logging activities, and recreational activities such as camping and picnicking (USDA Forest Service 2003(a)).

**Table 6.** Summary of data collected in Cow Creek watershed

| River | Year Monitored | River Miles Monitored | # of thermo-graphs | NMED | | | SFNF Standards | | | Districts |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | NF | AR | PF | NF | AR | PF | |
| Cow Creek | 2001 | 22.4 | 3 | 0 | 1 | 2 | 0 | 1 | 2 | Pecos/ Las Vegas |
| | 2002 | 22.4 | 3 | 0 | 3 | 0 | 0 | 3 | 0 | |
| Bull Creek | 2002 | unknown | 2 | 0 | 2 | 0 | 0 | 2 | 0 | Pecos/ Las Vegas |

(NF= not properly functioning, AR= at risk, PF= properly functioning).

## *Cow Creek*

Four temperature monitoring stations were established on Cow Creek (see Figure 58). The stations were not moved for the duration of the monitoring period. Temperatures were measured from July 11th to October 2001 and again in 2002 between June 5th and May 31st, 2003. Thermographs recorded temperatures at 16-minute intervals. The first station was placed in Reach 1 at the Forest Road 83 crossing below the confluence with Bull Creek (River Mile 15.9). The second was in Reach 5 also at a Forest Road 83 crossing. This thermograph was not recovered and so no data in available for this site. The third thermograph station was located just above the Cow Creek Campground (Reach 7, RM 28.5). The final thermograph was established just above the mouth of Elk Creek (Reach 10, RM 33.6).

Thermograph data collected between July 11th and September 30th, 2001 was used to determine water quality for that year. When Forest standards are applied, only one station (Thermograph Station 1) out of three was **at risk** (see Figure 59). None of the sites were classified as not properly functioning. Thermograph 1 was also the only station to record **at risk** days by NMED standards (see Figure 60). It had significantly more days properly functioning than at risk.

**Figure 59**. A comparison of not properly functioning, at risk, and properly functioning days at three thermograph locations between July 11th and September 30th, 2001. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on seven-day average maximum.

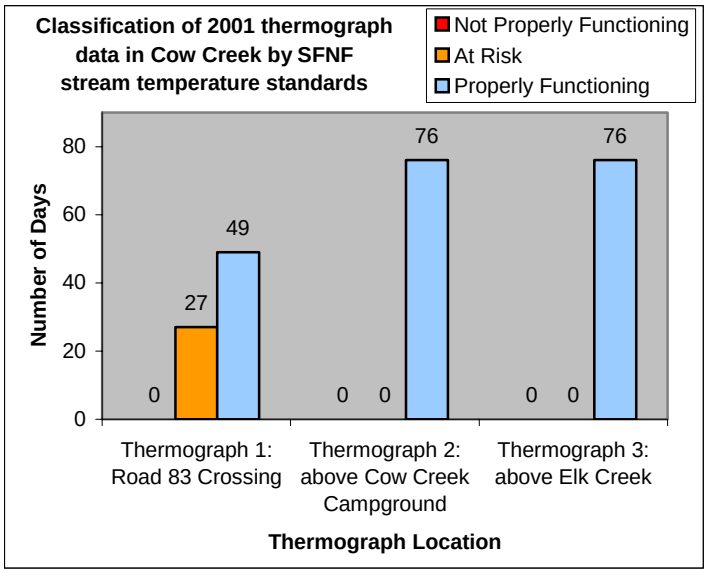
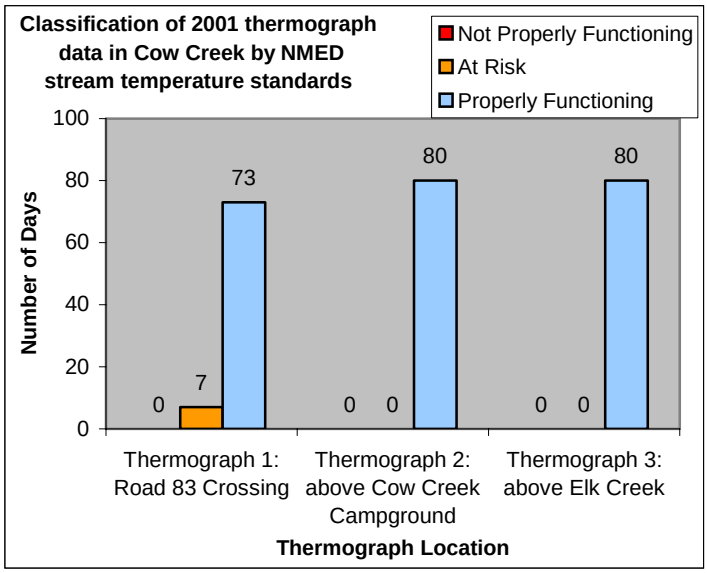



**Figure 60.** A comparison of not properly functioning, at risk, and properly functioning days at three thermograph locations between July 11th and September 30th, 2001. Water temperature categories defined by NMED Water Quality Temperature Standards are based on a three-day average maximum.




Thermograph data collected between June 5th and September 30th, 2002 was used to determine water quality for that year. When SFNF standards are applied all three stations were classified as **at risk**. None of the sites had not properly functioning days and all had more properly functioning days than at risk (see Figure 61). All three stations were also **at risk** by NMED water temperature standards (see Figure 62). At all sites, the number of days at risk was significantly less than the number of properly functioning days.

Looking at stream temperature across elevation can distinguish areas in need to temperature mitigation. On a typical system stream temperatures should increase as elevation decreases. In 2002, Cow Creek did not follow this pattern (see Figure 63). On July 31st, 2002 maximum stream temperatures were recorded at Thermograph Station 1 (elevation 6880'). Thermograph Station 3 (elevation 9200') had the second highest temperature of 59.2°F even though it was at a

higher elevation than Thermograph Station 2. This may be due to natural conditions (upwellings, coldwater springs, differing valley formations and aspect, etc.).

**Figure 61.** A comparison of not properly functioning, at risk, and properly functioning days at three thermograph sites in Cow Creek between June 5th and September 30th, 2002. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on a seven-day average maximum.

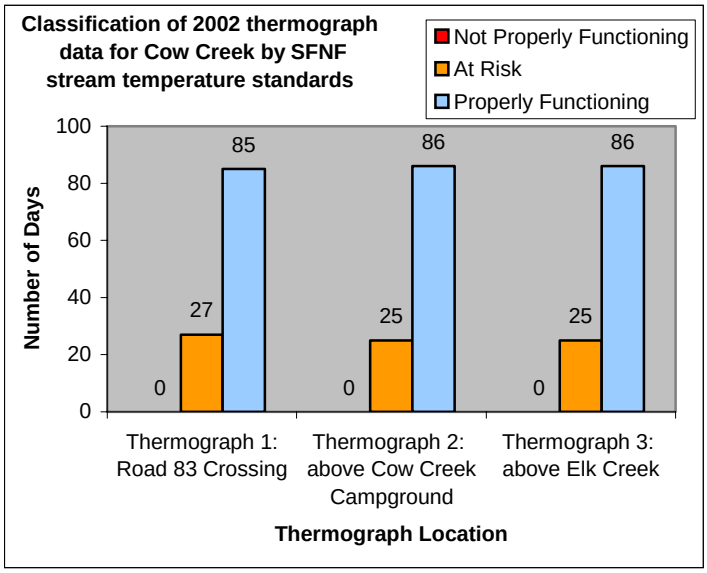
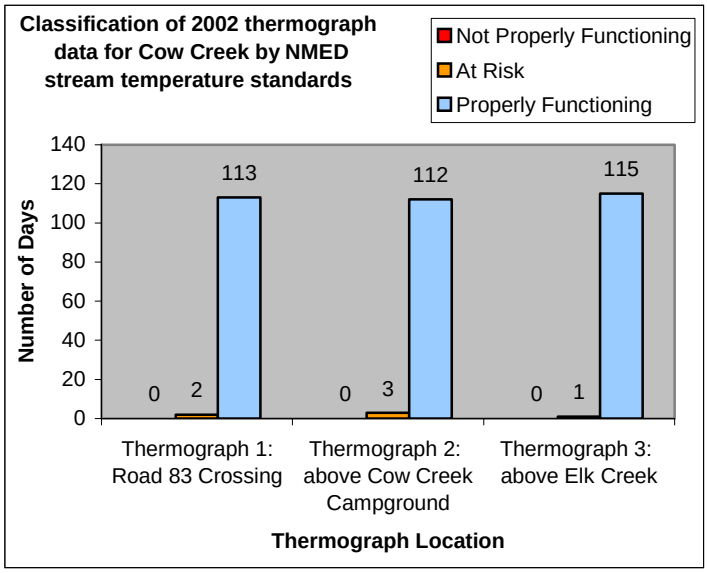



**Figure 62**. A comparison of not properly functioning, at risk, and properly functioning days at three thermograph sites in Cow Creek between June 5th and September 30th, 2002. Water temperature categories defined by NMED Water Quality Temperature Standards are based on a three-day average maximum.




Diurnal difference was analyzed from the thermograph stations. Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. Thermograph Station 3 (above Elk Creek) consistently recorded the highest diurnal differences (see Figure 64). Thermograph Station 1 (Road 83 crossing) on average had the lowest. On July 31st, 2002, diurnal fluctuations were lowest at the Thermograph Station 2 (3.1°F) and highest at Thermograph Station 3 (14°F). Thermograph Station 1 had a diurnal difference of 8.6°F.

**Figure 63.** Maximum stream temperatures on July 31st, 2002 across three thermograph stations on Cow Creek.

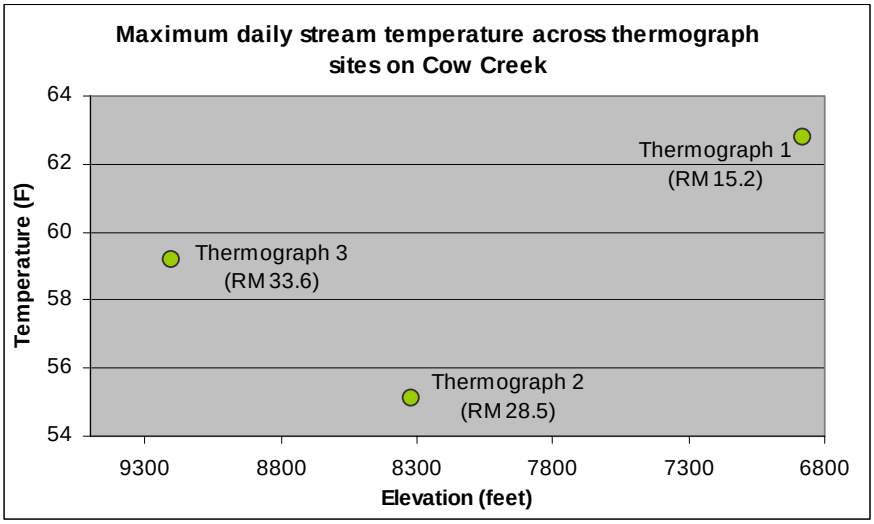
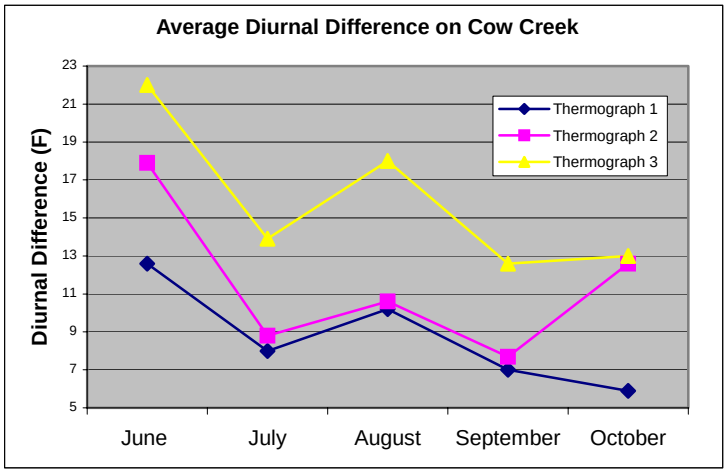


**Figure 64**. Diurnal difference averaged by month for three thermograph stations on Cow Creek.




The **at risk** classification of all sites by both standards implies water temperature should be a management consideration for Cow Creek. Temperature mitigating strategies should be applied to protect the integrity of the coldwater fishery.

In 2000, the Cow Creek Watershed experienced a catastrophic burn called the Viveash Fire. Prior to the fire there was little evidence of erosion in this watershed. A stream inventory conducted in 2001 found mass erosion, high sedimentation, and turbidity throughout the watershed due to the fire. Monitoring this system was recommended, but no temperature mitigation strategies were suggested until the system stabilizes (USDA Forest Service 2003(a)).

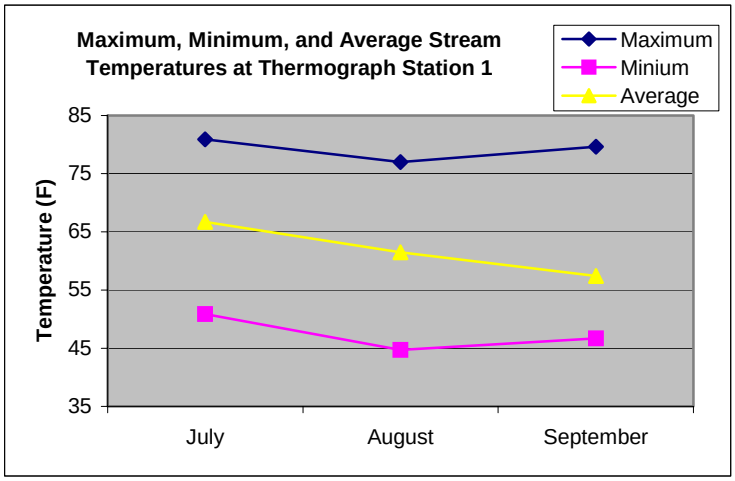
*Thermograph Station 1*: Road 83 Crossing
*Elevation*: 6880'
*Stream Mile*: 15.9

Thermograph Station 1 monitored 4.2 miles of Cow Creek. This section of Cow Creek flows primarily through private land. Thermograph data collected in 2001 determined Cow Creek at the Road 83 Crossing is **at risk**, exceeding the NMED standards 7 days out of 80 (8.8% of days) and SFNF standards 27 days out of 76 (35.5% of days). In 2002, the station was also **at risk** by NMED standards 1 day out of 116 (0.9% of days). By SFNF standards it was **at risk** 27 days out of 112 (24.1% of days).

In 2001, maximum stream temperatures were recorded in July, peaking at 80.9°F (see Figure 65). Stream temperatures decreased in August, but increased again in September to 79.6°F. Stream temperatures steadily decreased through the winter.

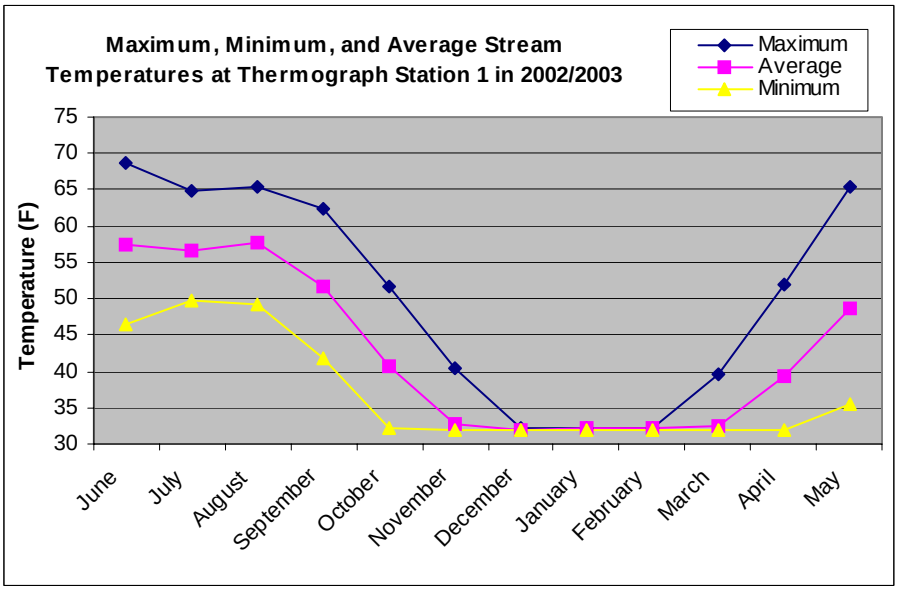
In 2002/2003, maximum stream temperatures were recorded in June (see Figure 66). Temperatures peaked at 68.8°F on June 19th. Temperatures decreased in July, but peaked again in August at 65.5°F. After August, temperatures decreased through November. They stabilized at 32.3°F, the approximate temperature where water freezes, for December through February. In March temperatures began to increase again until the thermograph was pulled in May.

**Figure 65**. Maximum, minimum, and average temperatures for each month in 2001 for the thermograph station at FS road 83 crossing.




In 2002, average monthly diurnal difference also peaked in June (see Figure 64). The maximum daily diurnal difference of 18.7°F was observed on June 19th, 2002. The daily minimum temperature fluctuation of 2.5°F occurred on September 11th, 2002.

**Figure 66.** Maximum, minimum, and average temperatures for each month in 2002/2003 for the thermograph station at FS road 83 crossing.

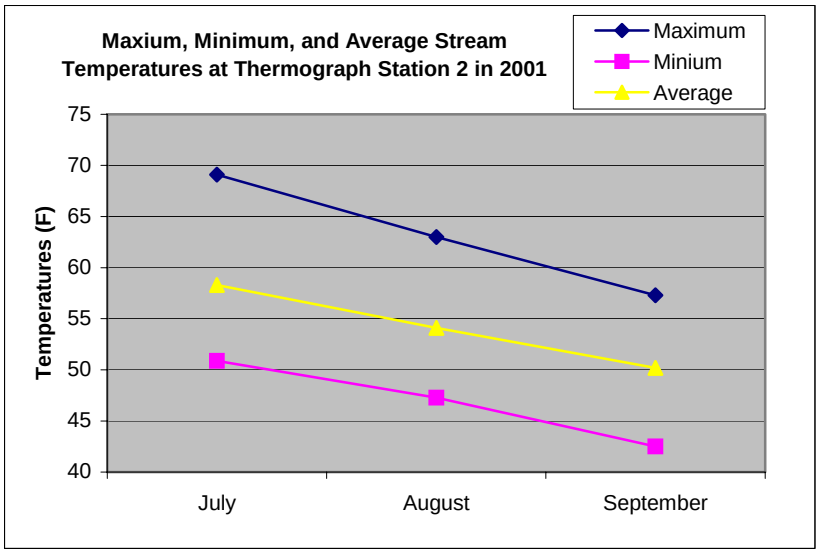



<u>*Thermograph Station 2*</u>: above Cow Creek Campground
*Elevation*: 8320'
*Stream Mile*: 15.2

Thermograph Station 2 monitored 5.3 miles of Cow Creek. This portion of Cow Creek is also primarily private land. There is one developed campground at the beginning of the reach. The stream flows primarily through an open meadow system that narrows into a canyon towards the top. Thermograph data collected in 2001 determined that Cow Creek above the Cow Creek Campground was **properly functioning** for both SFNF and NMED water quality standards. In 2002, this section of stream was classified as **at risk** 3 days of out of 115 by NMED standards (2.6% of days). It was also **at risk** 25 days of 111 by SFNF standards (22.5% of days).

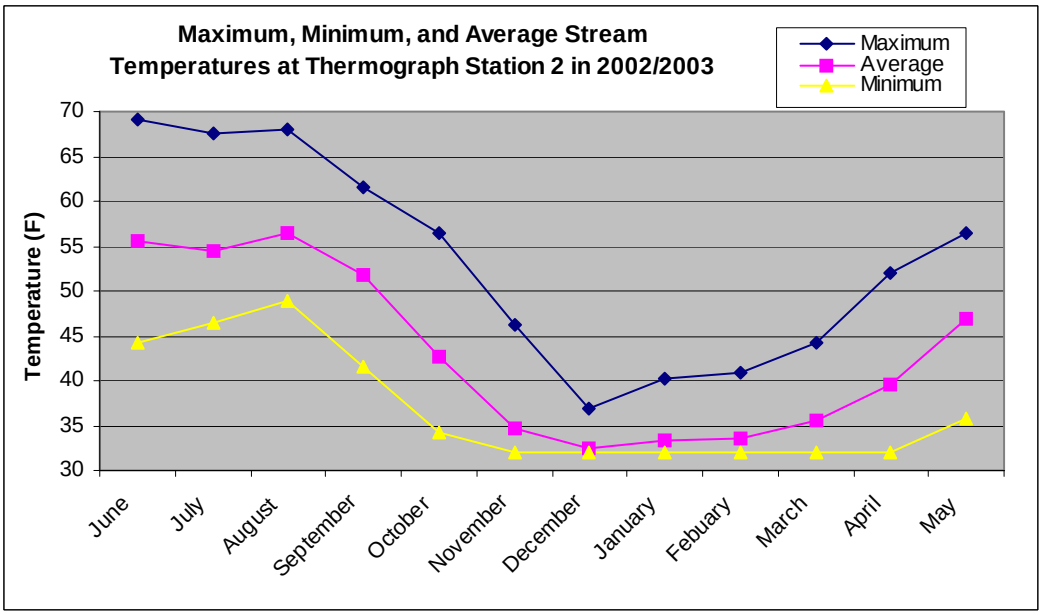
In 2001, stream temperatures peaked in July at 69.1°F. The recorded temperatures then decreased steadily through September (see Figure 67).

**Figure 67.** Maximum, minimum, and average temperatures for each month in 2001 for the thermograph station above Cow Creek Campground.




In 2002, stream temperatures also peaked at 69.1°F on June 18th. Temperatures then declined steadily through December. In January temperatures began to increase again and continued to increase until the thermograph was pulled in May 2003 (see Figure 68).

**Figure 68.** Maximum, minimum, and average temperatures for each month in 2002/2003 for the thermograph station above Cow Creek Campground.



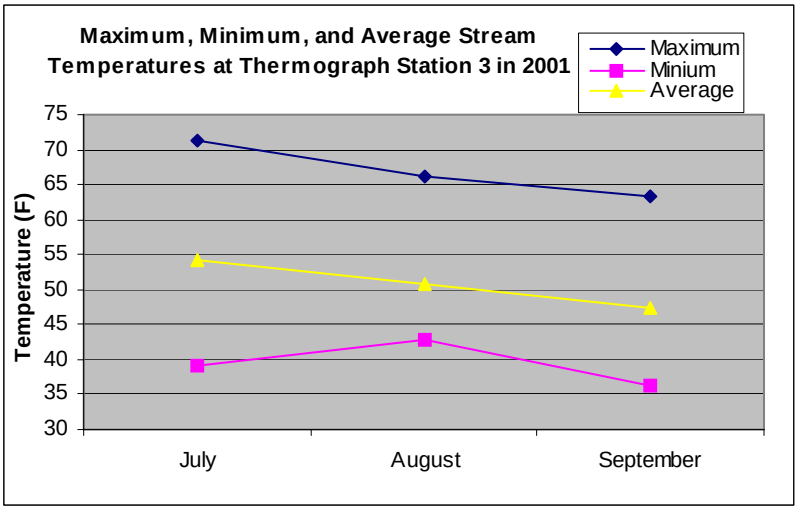

Average monthly diurnal difference also peaked in June 2002 (see Figure 64). The maximum daily diurnal difference of 24.7°F was observed on June 13th. The minimum daily temperature fluctuation of 1.7°F occurred on August 28th.

*Thermograph Station 3*: above Elk Creek
*Elevation*: 9200'
*Stream Mile*: 33.6

Thermograph Station 3 monitored 4.2 stream miles. This section of Cow Creek flows through a narrow canyon until it reaches the headwaters. Thermograph data collected in 2001 determined that Cow Creek above Elk Creek was **properly functioning**. In 2002, this stretch of stream was classified as **at risk** 2 days out of 115 (1.7% of days) by NMED standards and 25 days out of 111 by SFNF standards (22.5% of days).

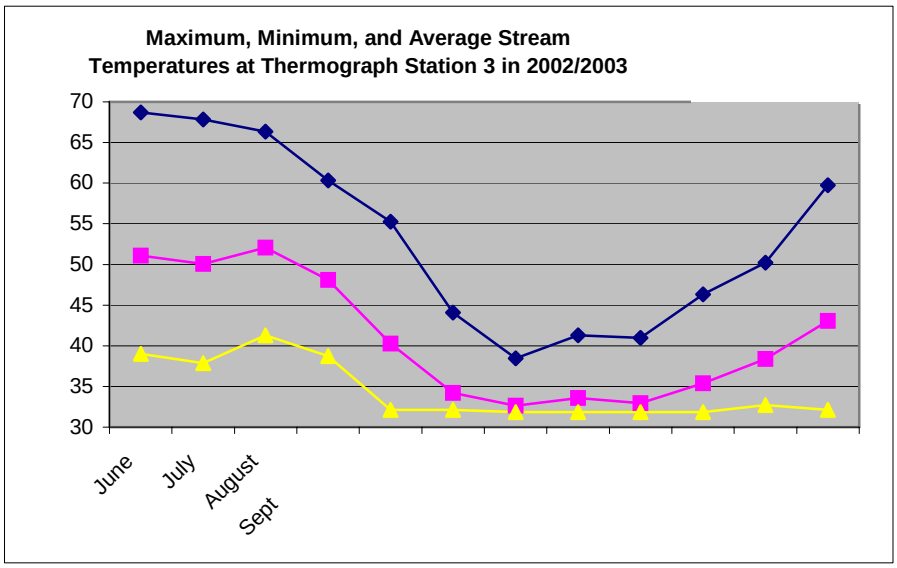
In 2001, stream temperatures peaked at 71.4°F in July. Temperatures then decreased steadily through September (see Figure 69).

**Figure 69.** Maximum, minimum, and average temperatures for each month in 2001 for the thermograph station above Elk Creek.




In 2002, maximum stream temperatures were recorded in June (see Figure 70). Temperature peaked at 68.7°F on June 18th. From July through December temperatures decreased steadily. In January temperatures began to increase again until the thermograph was pulled in May 2003.

**Figure 70.** Maximum, minimum, and average temperatures for each month in 2002/2003 for the thermograph station located above Elk Creek.



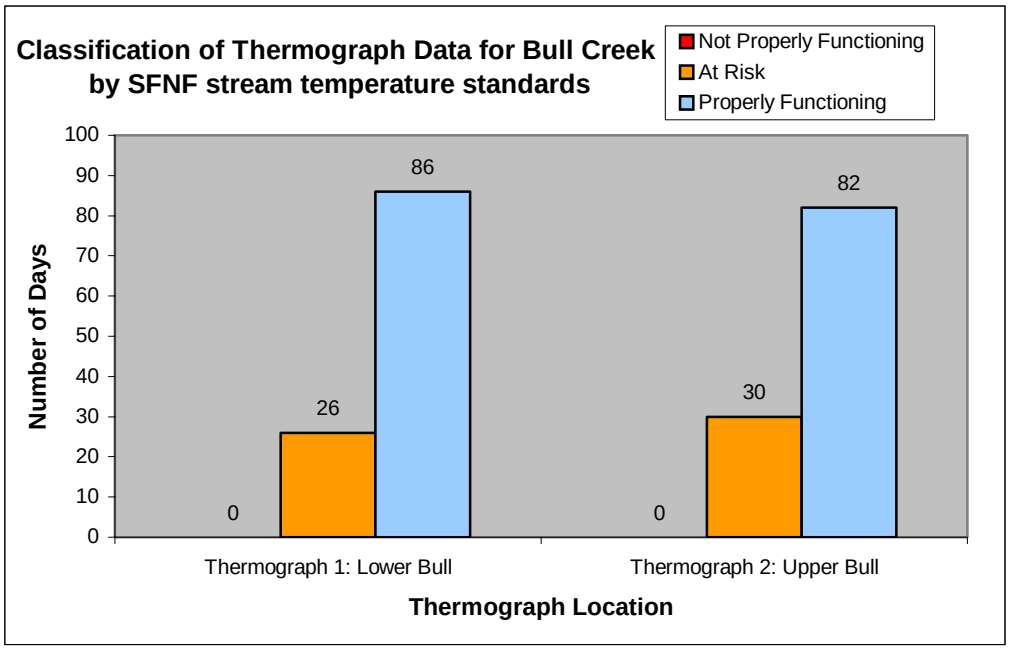
Average monthly diurnal difference also peaked in June (see Figure 64). In 2002, diurnal difference was calculated for the months of June through October. The maximum daily diurnal difference in 2002 of 29.1°F was observed on June 13th. The minimum diurnal difference of 3.3°F occurred on September 10th.

## *Bull Creek*

Two thermograph stations were established on Bull Creek. The stations were not moved for the duration of the monitoring period. Water temperature was monitored from June 5th, 2002 to June 1st, 2003. Thermographs recorded temperatures at 15-minute intervals. The exact locations of the two thermographs monitoring Bull Creek is unknown (personnel who deployed Tidbits are no longer employed by SFNF and no information was left behind to denote the exact location).

Thermograph data collected between June 5th and September 30th, 2002 was used to determine water quality. When SFNF standards are applied both stations are **at risk**, although the number of properly functioning days out number at risk days (see Figure 71). Neither of the sites have not properly functioning days.

**Figure 71.** A comparison of not properly functioning, at risk, and properly functioning days at two thermograph sites in Bull Creek between June 5th and September 30th, 2002. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on a seven-day average maximum.

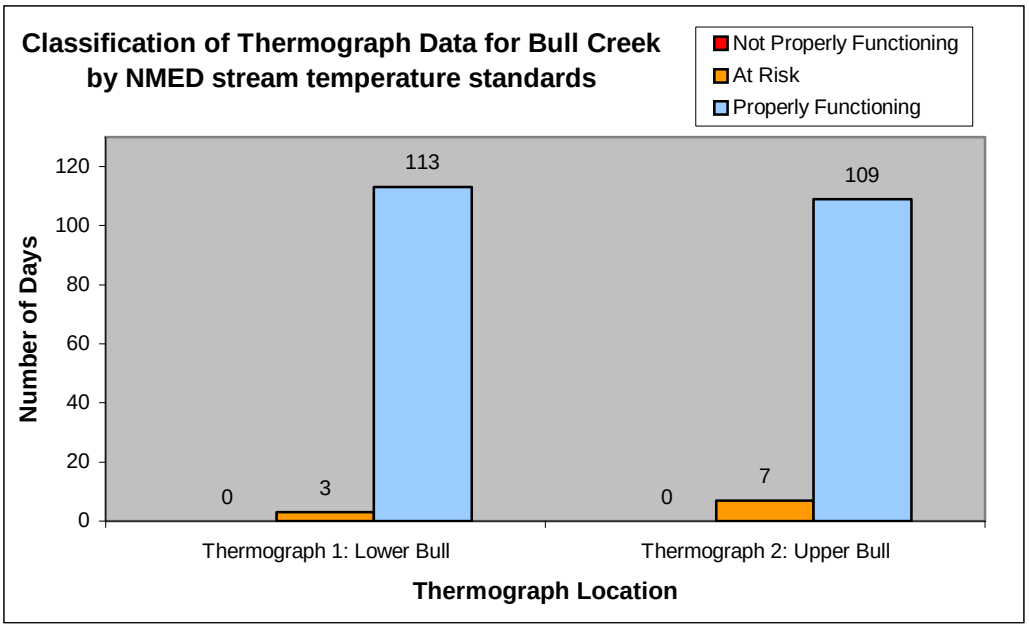



Both stations also recorded **at risk** days when classified by NMED standards, although the number of days recorded at risk was significantly lower than the number of days properly functioning (see Figure 72). Neither site recorded not properly functioning days.

Looking at stream temperatures across elevation can also distinguish areas in need of temperature mitigation. On a typical system, temperatures should increase as elevation decreases. Bull Creek follows this pattern. On July 31st, maximum temperatures varied from 63.1°F at the Upper Bull Creek station to 62.8°F at the Lower Bull Creek station.

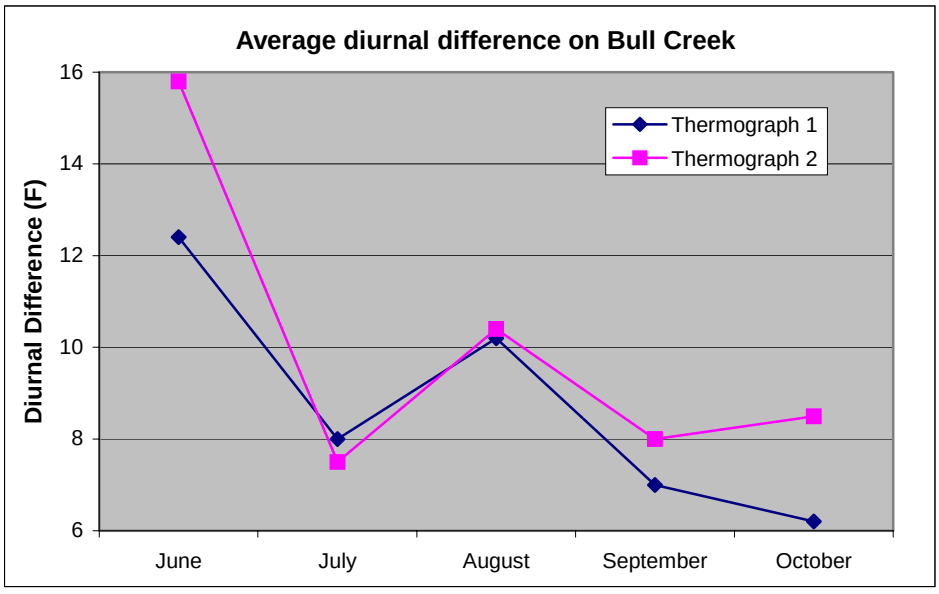
Diurnal difference was analyzed from the thermograph stations. Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. Again, on July 31st in Bull Creek, diurnal difference ranged from 7.4°F at the Upper Bull Creek station to 8.6°F at the Lower Bull station. On average, Thermograph Station 2 had the highest diurnal differences (see Figure 73).

**Figure 72.** A comparison of not properly functioning, at risk, and properly functioning days at two thermograph sites in Bull Creek between June 5th and September 30th, 2002. Water temperature categories defined by NMED Water Quality Temperature Standard are based on three-day average maximum.




The **at risk** classification of both sites by both standards implies water temperature should be a management consideration for Bull Creek. Temperature mitigating strategies should be applied to protect the integrity of the coldwater fishery. A survey was conducted in 2002 to determine factors influencing stream temperature. This survey data has not yet been analyzed.

**Figure 73**. Diurnal difference averaged by month for two thermograph stations on Bull Creek.

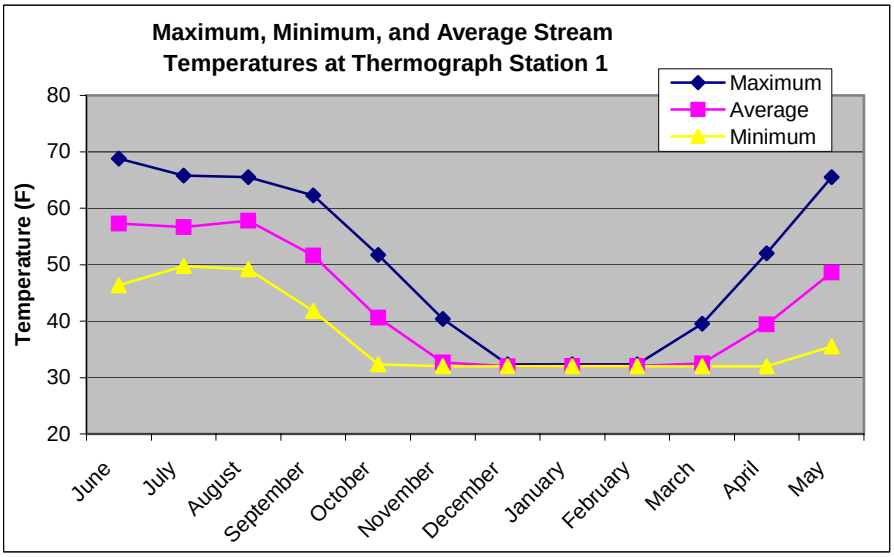


*Thermograph Station 1*: Lower Bull
*Elevation:* unknown
*Stream Mile:* unknown

Thermograph data collected in 2002 determined the Lower Bull thermograph station was **at risk**, exceeding NMED standards 3 days out of 116 (2.7% of the days). The site was also **at risk** by SFNF standards 26 days out of 112 (23.2% of the days).

Maximum stream temperatures were recorded in June. On June 19th, the stream temperature peaked at 68.8°F. Temperatures then decreased steadily until December when they leveled out around 32°F, the approximate temperature where water freezes. Temperatures began increasing again in March and continued to rise until the thermograph was pulled in May 2003 (see Figure 74).

**Figure 74.** Maximum, minimum and average temperatures for each month for Thermograph Station 1 in Lower Bull Creek.



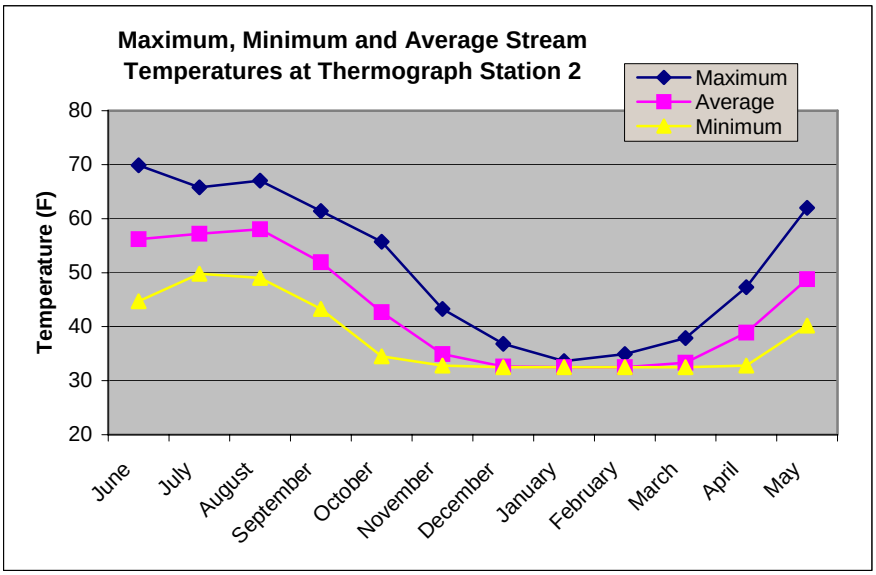

Average monthly diurnal difference peaked in June and then again in August (see Figure 73). The maximum daily stream fluctuation of 18.7°F occurred on June 19th, 2002. The minimum daily diurnal difference of 0°F occurred frequently throughout the months of December, January, and February. A layer of frozen water over or around the thermograph would insulate the thermograph from daily fluctuations due to air temperature.

*Thermograph Station 2*: Upper Bull
*Elevation:* unknown
*Stream Mile:* unknown

Thermograph data collected in 2002 determined the Upper Bull thermograph station was **at risk**, exceeding the NMED standard 7 days out of 116 (6.0% of days). The site was also **at risk** by SFNF standards 30 days out of 112 days (26.8% of days).

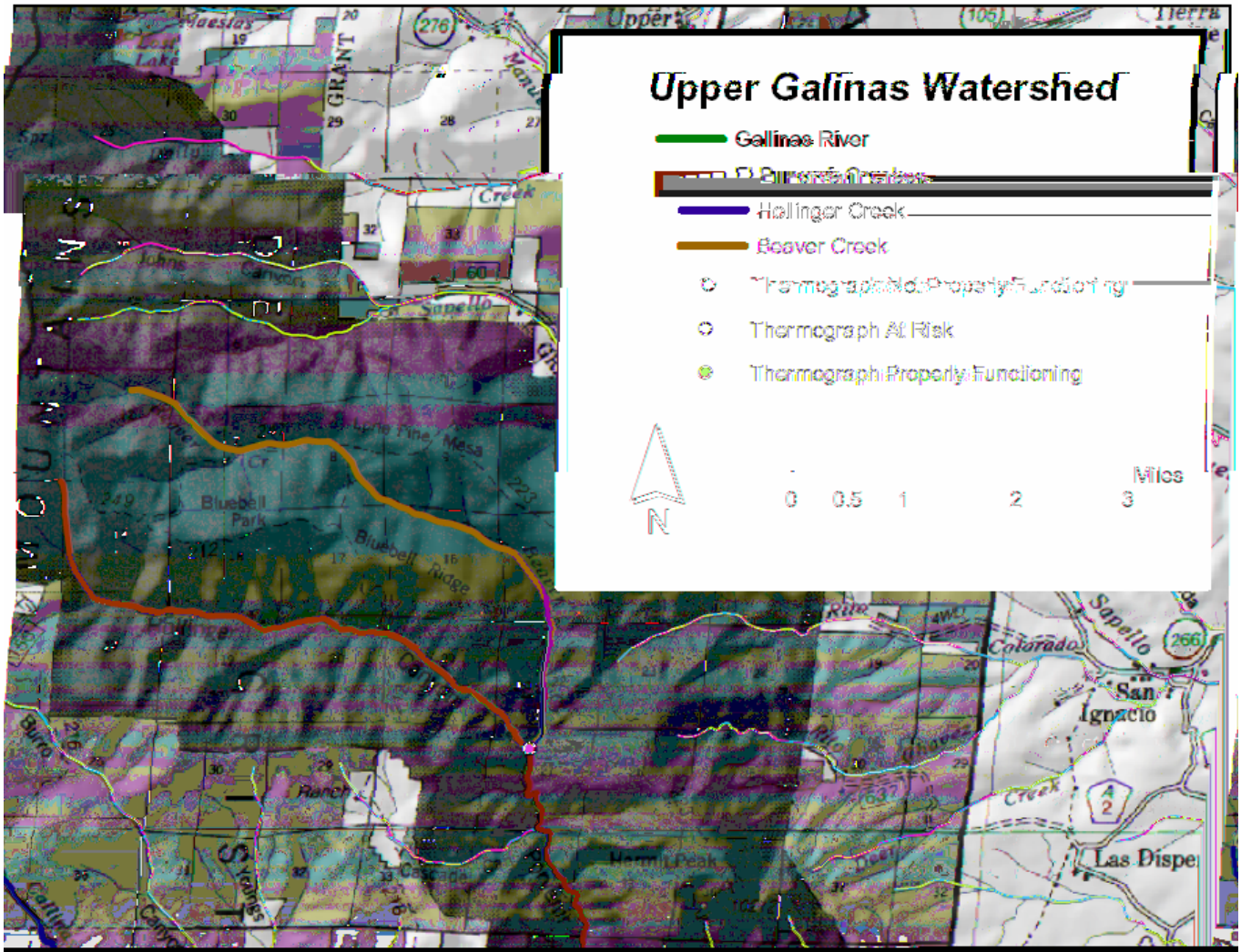
Maximum temperatures were recorded in June. The maximum daily temperature of 69.9°F was observed on June 10th, 2002. Stream temperature peaked again in August (at 67°F), and then decreased steadily through January. In February the temperatures began to increase again until the thermograph was pulled at the end of May (see Figure 75).

**Figure 75**. Maximum, minimum, and average temperatures for each month for Thermograph Station 2 located in Upper Bull Creek.




Average monthly diurnal difference also peaked in June at 15.8°F. It peaked again in August at 10.4°F (see Figure 73). The maximum daily fluctuation of 23.8°F was observed on June 10th, 2002. A diurnal difference of 0°F was recorded regularly throughout the months of December, January and February. A layer of frozen water over or around the thermograph would insulate the thermograph from daily fluctuations due to air temperature.

Figure 76. Map of thermograph locations in Upper Gallinas Watershed. Stream temperature classifications are based on SFNF standards.



# Upper Gallinas Watershed

Gallinas Watershed is located on the east side of the Sangre de Cristo Mountains and is managed by Pecos/Las Vegas Ranger Districts. Streams generally flow west to east and eventually enter the Gallinas River. The watershed's management is guided by Wilderness and Santa Fe National Forest Land and Resource Management Plan. The watershed has been listed as impaired under Section 303(d) of the Clean Water Act by New Mexico Environment Department. The impairments include stream bottom deposits, stream temperature, turbidity, and acute aluminum (NMED 2003).

In 2000, a catastrophic fire called the Viveash Fire passed through a portion of this watershed on Forest Service land. Forty-one (41%) of the watershed burned, and 13% of it burned severely. A stream survey conducted after the fire noted a lack of pool development and large woody debris. Surveyors also noted increased run off and sediment production due to the fire. In addition to the Viveash burn, management activities in the watershed that may be affecting stream temperature include grazing, road construction in the floodplain, historic logging activities, fuel wood removal, and recreational activities including camping in developed and dispersed sites (USDA Forest Service Fisheries Program files).

**Table 7.** Summary of data collected in Upper Gallinas Watershed

| River | Year Monitored | River Miles Monitored | # of thermo-graphs | NMED | | | SFNF Standards | | | Districts |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | NF | AR | PF | NF | AR | PF | |
| Gallinas | 2001 | 7.7 | 2 | 0 | 0 | 2 | 0 | 0 | 2 | Pecos/ Las Vegas RD |
| El Porvenir | 2002 | 7.3 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | Pecos / Las Vegas RD |
| Beaver | 2002 | 5.9 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | Pecos/ Las Vegas RD |
| Hollinger | 2002 | 5.7 | 1 | 0 | 0 | 1 | 0 | 1 | 0 | Pecos/ Las Vegas RD |

(NF= not properly functioning, AR= at risk, PF= properly functioning).

## *Gallinas River*

Two temperature monitoring stations were established on Gallinas River (see Figure 76). The stations were not moved for the duration of the monitoring period. Monitoring was conducted between July 10th, 2001 and May 2002. Thermographs recorded temperatures at 16-minute intervals. The first station was placed near a Forest Service administrative site (in Reach 3 of the 2001 survey, River Mile 81.3). The second station was placed at the end of Forest Road 263 (in Reach 7, River Mile 86.8).

Thermograph data collected between July 10th and September 30th was used to determine water quality. When Forest and NMED standards are applied, both stations were **properly functioning** (see Figures 77 and 78).

**Figure 77**. A comparison of not properly functioning, at risk, and properly functioning days at two thermograph stations on Gallinas River between July 10th and September 30th, 2001. Temperature categories defined by SFNF Water Quality Temperature Standards are based on a seven-day average maximum.

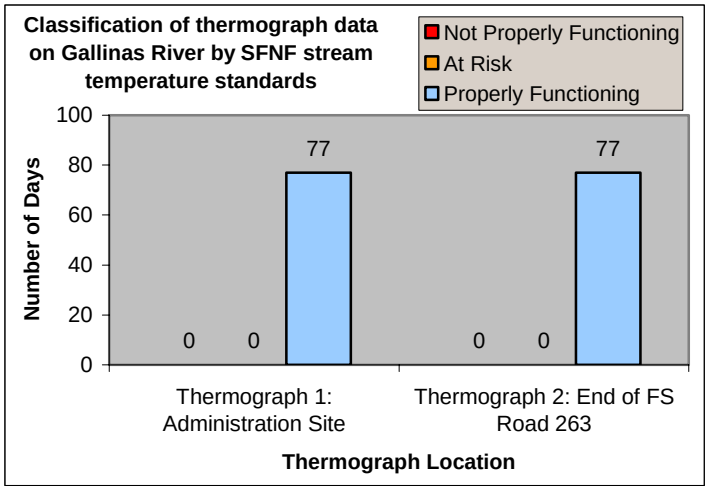



**Figure 78**. A comparison of not properly functioning, at risk, and properly functioning days at two thermograph stations on Gallinas River between July 10th and September 30th, 2001. Water temperature categories defined by NMED Water Quality Temperature Standards are based on a three-day average maximum.

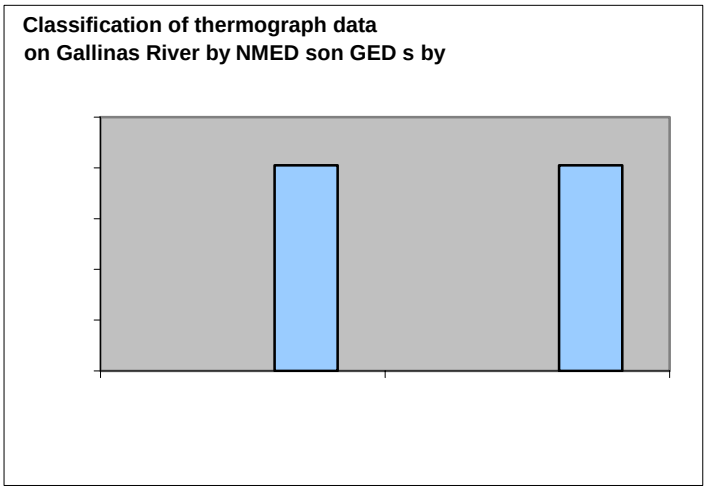
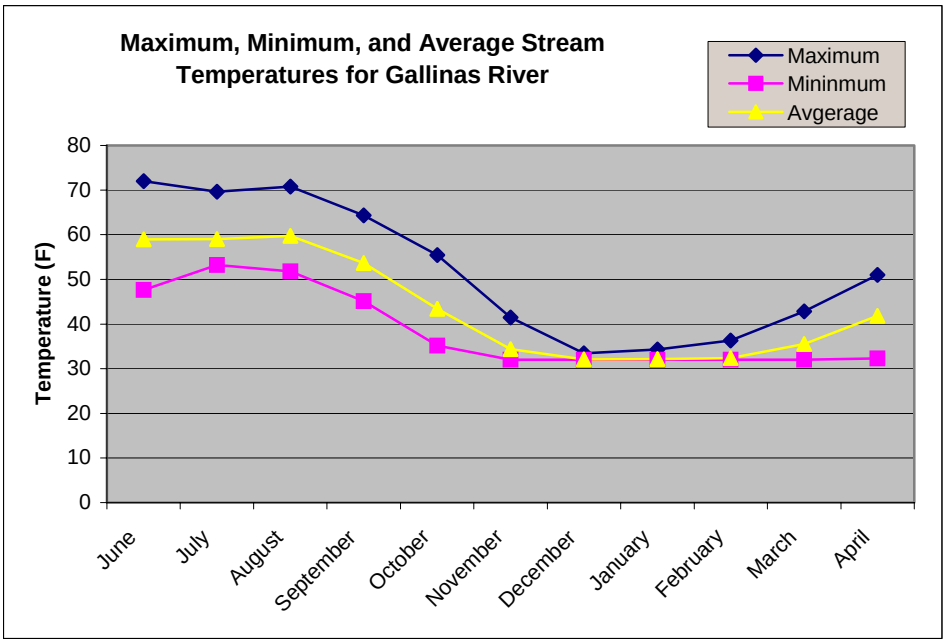
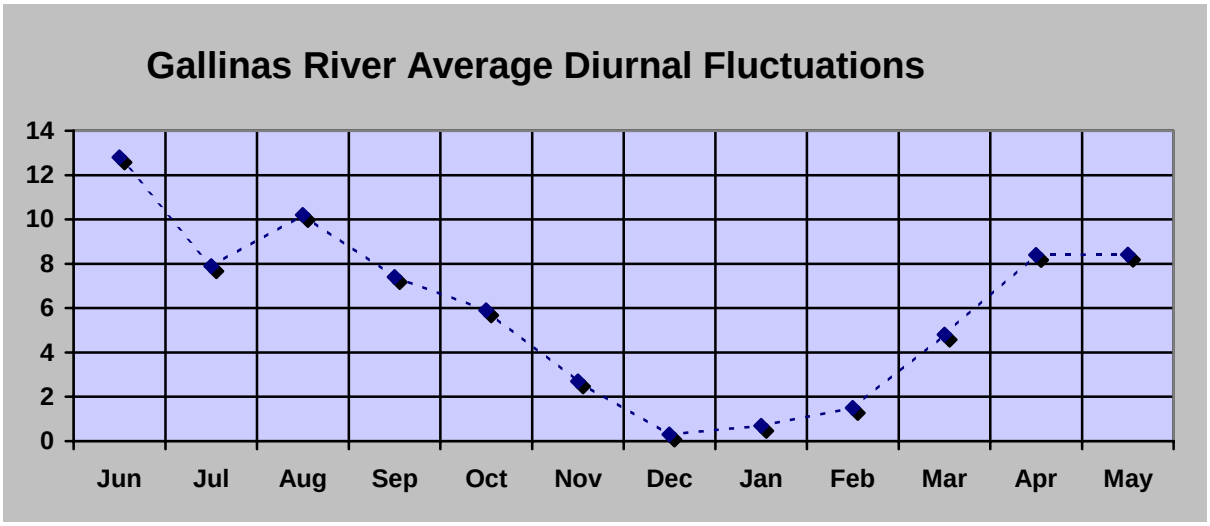


**Figure 79**. Maximum, Minimum, and Average temperatures for each month on the Gallinas River.




Average monthly diurnal difference also peaked in June and July (see Figure 80). Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum.

**Figure 80.** Diurnal difference averaged by month for Gallinas River.




<u>*Thermograph Station 1*</u>: Administration Site
*Elevation*: 7500'
*Stream Mile*: 81.3

Thermograph Station 1 monitored 5.5 miles of stream. This section of Gallinas River is paralleled by Forest Road 263 and sees a large amount of recreational use. A series of developed picnic areas are found throughout. Approximately one mile of this reach passes through private land. Thermograph data collected in 2001 determined Gallinas River at the administration site was **properly functioning** for the entire period monitoring by both standards.

*Thermograph Station 2*: End of Forest Road 263
*Elevation*: 8600'
*Stream Mile*: 86.8

Thermograph Station 2 monitored 2.2 miles of stream. The headwaters of Gallinas River are reached at the end of this monitored length. Forest Service Trail 216 parallels this section of stream. The river valley gets progressively narrower over the length of the stream. Thermograph data collected in 2001 determined Gallinas River above Forest Road 263 was **properly functioning** all 95 days by both NMED and SFNF standards.

## *El Porvenir Canyon*

One temperature monitoring station was established at the mouth of El Porvenir Canyon (see Figure 76). The station was not moved for the duration of the monitoring period. This thermograph monitored the 7.3 mile length of the creek. Water temperature was monitored from June 3rd, 2002 to May 30th, 2003. The thermograph recorded temperatures at 16-minute intervals.

Thermograph data collected between June 3rd and September 30th, 2002 was used to determine water quality. El Porvenir (River Mile 0) is **at risk** by SFNF and NMED standards. The thermograph station had 31 days **at risk** (27.2% of days) out of 114 by SFNF standards (see Figure 81). Two days (1.7% of days) out of 118 were **at risk** by NMED standards (see Figure 82).

**Figure 81**. A comparison of not properly functioning, at risk, and properly functioning days at the El Porvenir thermograph station between June 3rd and September 30th, 2002. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on a seven-day average maximum.

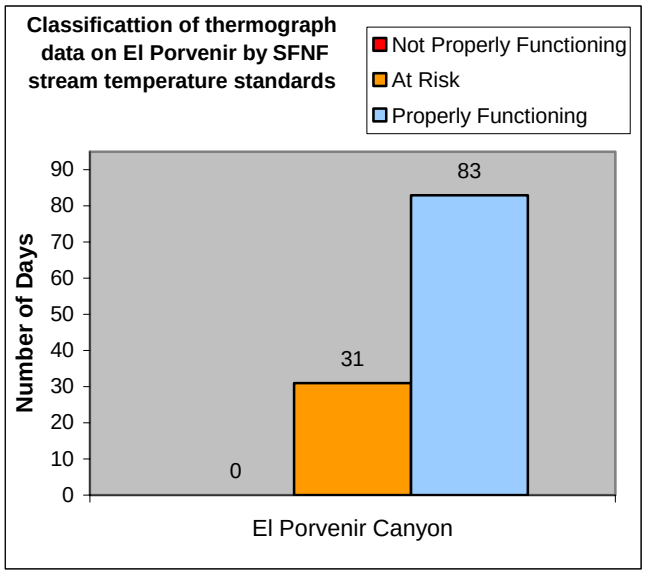
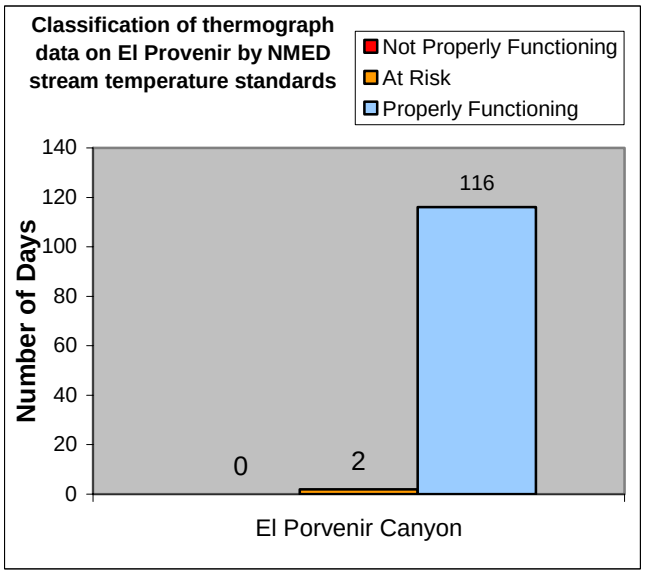


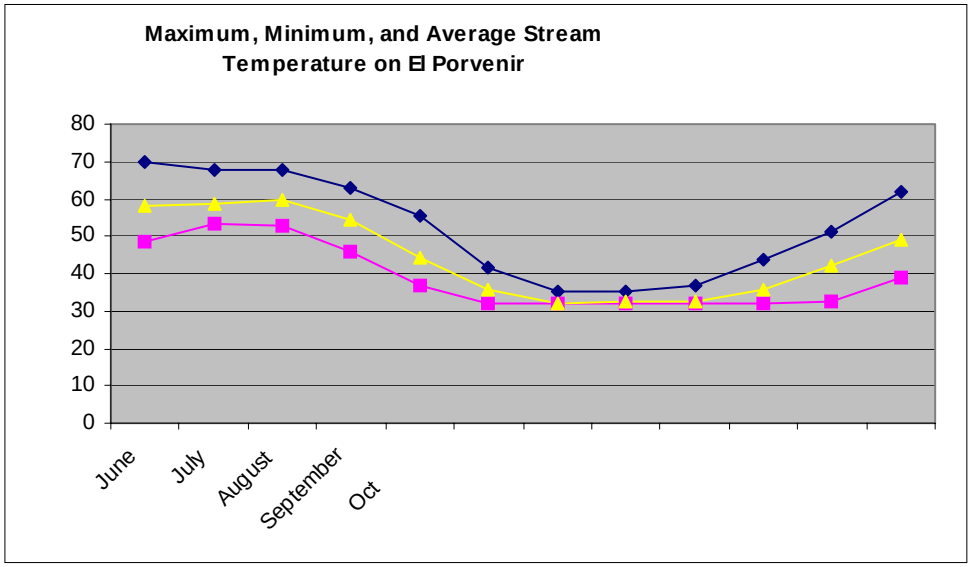

**Figure 82**. A comparison of not properly functioning, at risk, and properly functioning days at the El Porvenir thermograph station between June 3rd and September 30th, 2002. Water temperature categories defined by NMED Water Quality Temperature Standards are based on a three-day average maximum.




Maximum stream temperatures were recorded in June (Figure 83). Temperature peaked at 70°F on June 19th, 2002. After June, temperatures decreased steadily through January. Post- January temperatures increased through May when the thermograph was pulled.
Average monthly diurnal difference also peaked in June (see Figure 84).

In 2002, diurnal difference was calculated for the months of June through October. Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. The maximum daily difference of 19.2°F was observed on June 19th, 2002. The minimum difference of 2°F was recorded on September 11th, 2002.

**Figure 83**. Maximum, minimum and average temperatures for each month at the thermograph station on El Porvenir.



## *Beaver Creek*

One temperature monitoring station was established at the mouth of Beaver Creek (River Mile 0.0). This thermograph monitored the 5.9 mile length of the creek. Water temperature was monitored from July 11th, 2002 to June 24th, 2003. The thermograph recorded temperatures at 16-minute intervals. The station was not moved for the duration of the monitoring period.

Thermograph data collected between July 11th and September 30th, 2002 was used to determine water quality. When both SFNF and NMED standards were applied Beaver Creek was **properly functioning** (see Figures 85 and Figure 86). The site had no at risk or not properly functioning days.

**Figure 85.** A comparison of not properly functioning, at risk, and properly functioning days at a thermograph station in Beaver Creek between July 11th and September 30th, 2002. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on a seven-day average maximum.

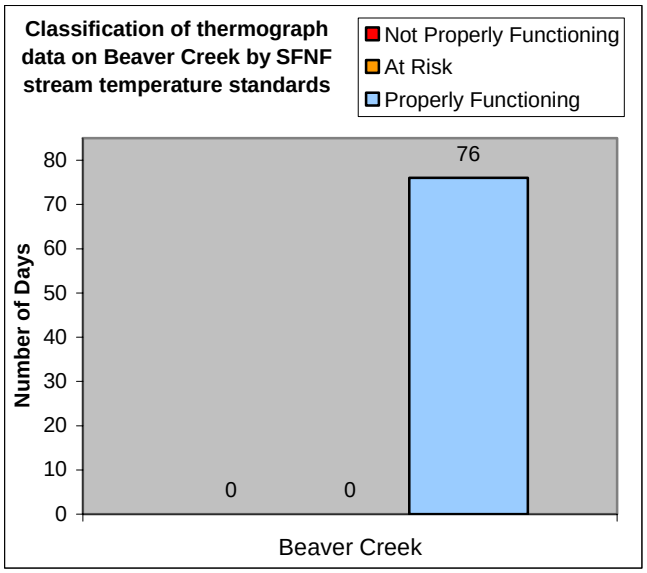
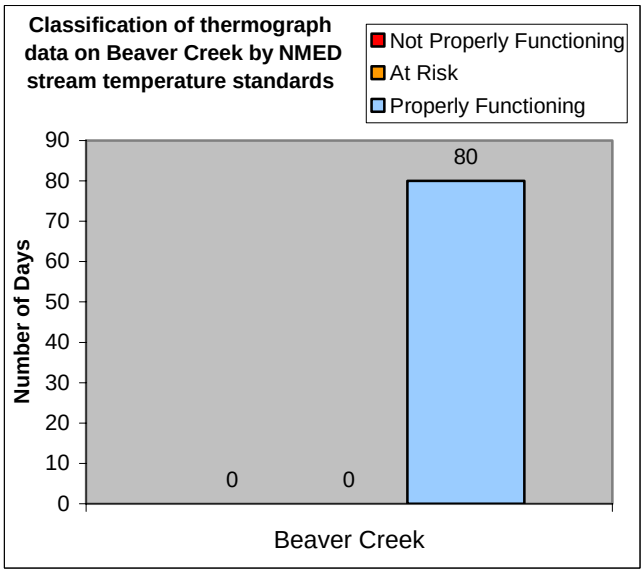


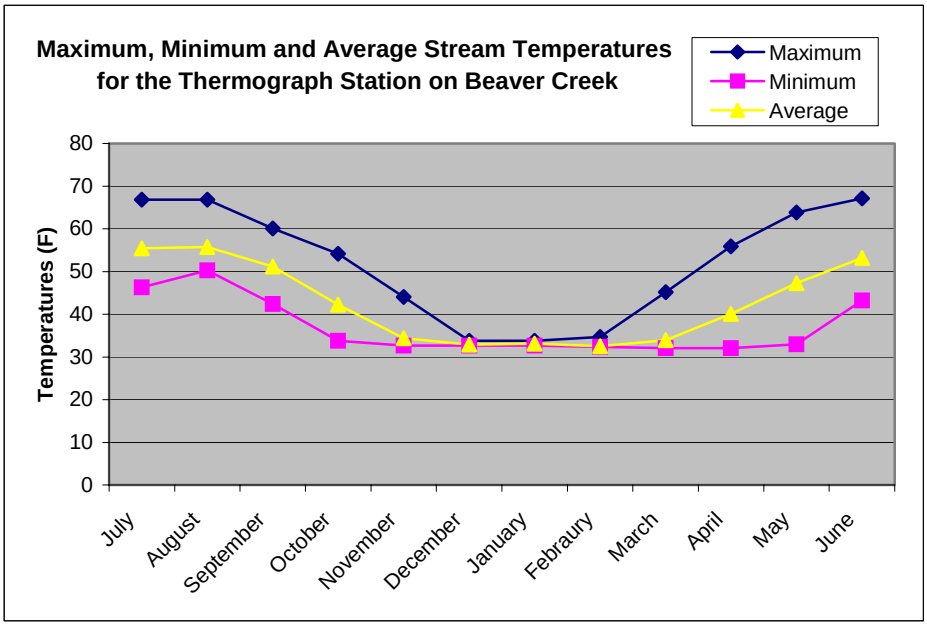

**Figure 86**. A comparison of not properly functioning, at risk, and properly functioning days at the Beaver Creek thermograph station between July 11th and September 30th, 2002. Water temperature categories defined by NMED Water Quality Temperature Standards are based on a three-day average maximum.




Maximum temperatures for this system were recorded in June of 2003 (see Figure 87). In 2002, temperatures peaked at 66.8°F on July 17th and again on August 20th. Temperatures declined from there until February when temperatures began to increase again. Stream temperatures reached their maximum of 67.1°F on June 22nd and were pulled the next day.

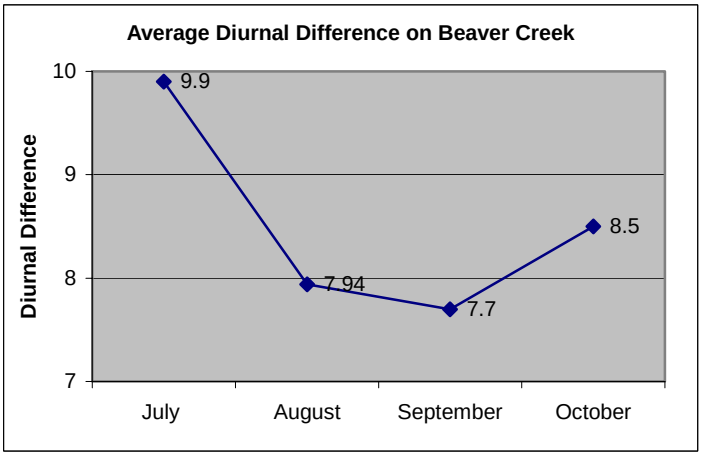
Diurnal difference was calculated for July through October of 2002 (see Figure 88). Average monthly diurnal difference peaked in July. Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. The daily maximum diurnal difference of 18°F was observed on July 17th. The daily minimum diurnal difference of 2.5°F occurred on August 13th.

**Figure 87.** Maximum, minimum, and average temperatures for each month for the thermograph station on Beaver Creek.




The properly functioning classification by both SFNF and NMED water quality standards means this stream can support a healthy coldwater fishery. This system should be maintained in its current state. A stream inventory was conducted in 2002 to determine to identify any threats to maintaining proper stream function. This data has not yet been analyzed.

**Figure 88.** Diurnal difference averaged by month for the thermograph station on Beaver Creek.



## *Hollinger Creek*

One temperature monitoring station was established at the mouth of Hollinger Creek (see map page 84). The station was not moved for the duration of the monitoring period.
This thermograph monitored the 5.7 mile stream. Water temperature was monitored at this location from July 11th, 2002 through June 23rd, 2003. The thermograph recorded temperatures at 16-minute intervals.

Thermograph data collected between July 11th and September 30th, 2002 was used to determine water quality. When Forest standards are applied Hollinger Creek was classified as **at risk** (see Figure 89). Twelve (12) days (15.8% of days) out of 76 were at risk. No days were not properly functioning. By NMED standards, Hollinger Creek is **properly functioning** all 80 days (see Figure 90).

**Figure 89**. A comparison of not properly functioning, at risk, and properly functioning days at the Hollinger Creek thermograph station between July 11th and September 30th, 2002. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on a seven-day average maximum.

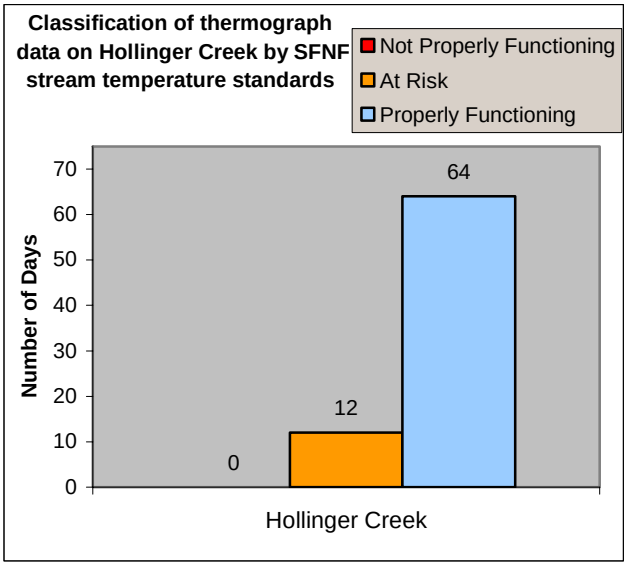
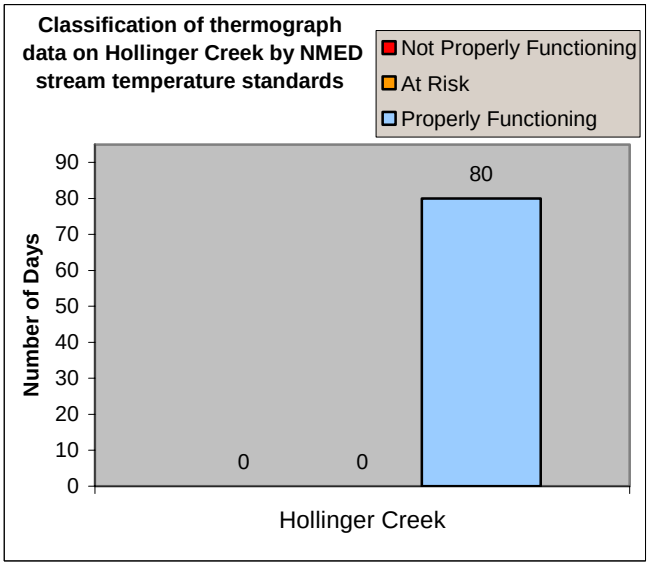


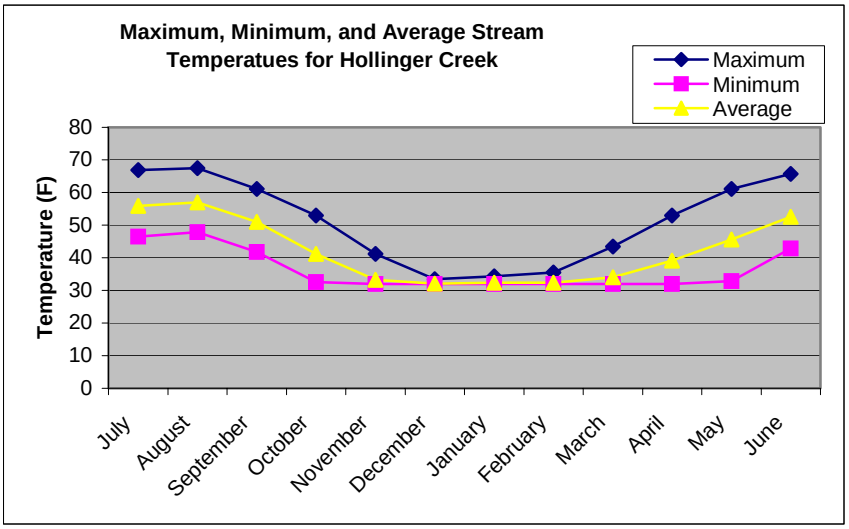

**Figure 90**. A comparison of not properly functioning, at risk, and properly functioning days at the Hollinger Creek thermograph station between July 11th and September 30th, 2002. Water temperature categories defined by NMED Water Quality Temperature Standards are based on a three-day average maximum.




Maximum temperatures in Hollinger Creek were recorded in August 2002 (see Figure 91). Temperatures peaked at 67.5°F on August 20th, 2002 and then decreased steadily through December. In January temperatures began to gradually increase again and continued to increase through June when the thermograph was pulled.

Average monthly diurnal difference was calculated for July through October 2002 (see Figure 92). Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. The average monthly diurnal difference peaked in August. The maximum daily diurnal difference of 17.3°F was observed on July 17th. The minimum daily diurnal difference of 3.1°F was recorded on July 22nd.

**Figure 91**. Maximum, minimum and average for each month for the thermograph station on Hollinger Creek.




The **at risk** classification of this site by SFNF water quality standards implies that water temperature should be a management consideration for Hollinger Creek. Temperature mitigating strategies should be applied to protect the integrity of the coldwater fishery. A stream survey of Hollinger Creek was completed in 2002. The survey data has not been analyzed to identify factors increasing stream temperatures.

**Figure 92.** Diurnal difference averaged by month for the thermograph station on Hollinger Creek.

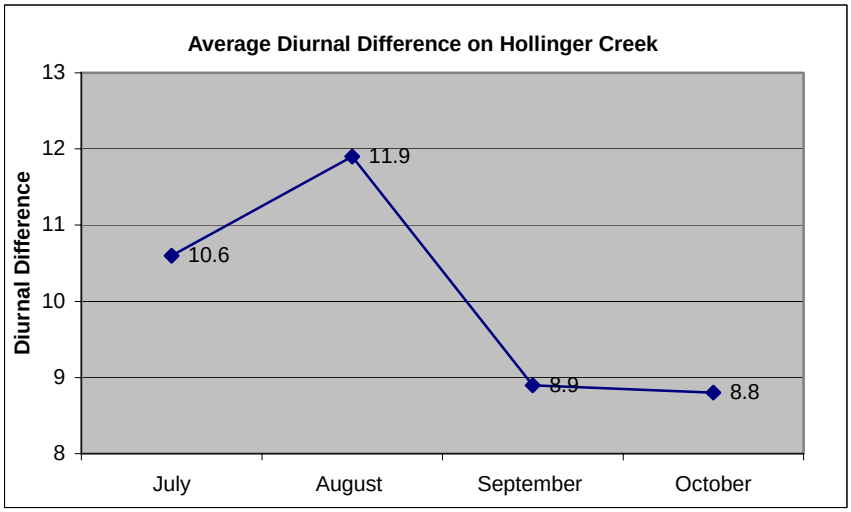
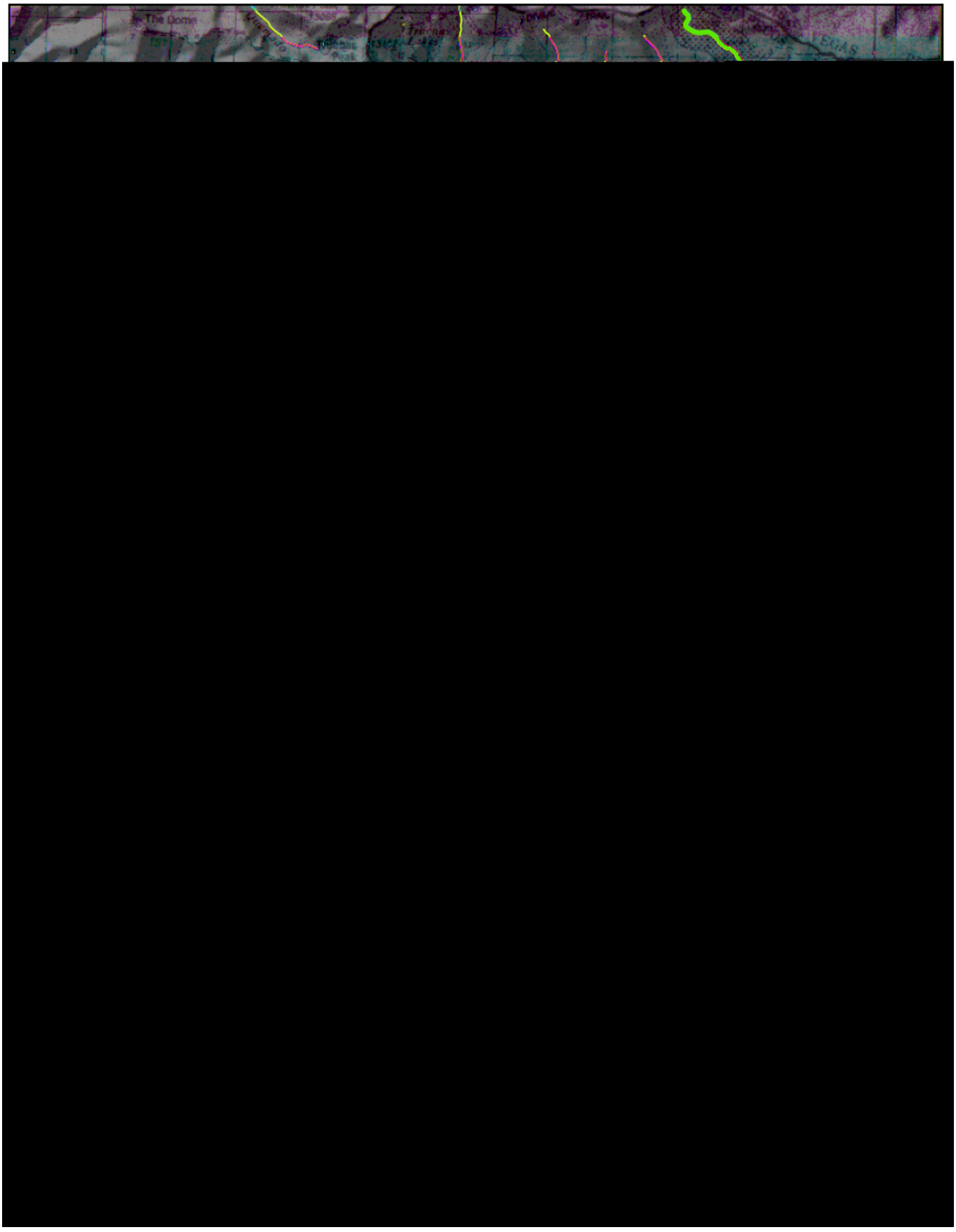


Figure 93. Map of thermograph locations in Pecos Headwaters Watershed. Stream temperature classifications are based on SFNF standards.



# Pecos Headwaters Watershed

The Pecos Headwaters Watershed is located on the east side of the Sangre de Cristo Mountains and is managed by Pecos/Las Vegas Ranger Districts. Streams flow mostly north to south and eventually into the Pecos River. The watershed's management is guided by special designation as a Wild and Scenic River, Wilderness, Santa Fe National Forest Land and Resource Management Plan. The watershed has been listed as impaired under Section 303(d) of the Clean Water Act by New Mexico Environment Department. The impairments include stream bottom deposits and turbidity (NMED 2003).

Recent stream surveys noted sections of streams in the wilderness areas exhibited fairly pristine conditions; whereas, areas outside the wilderness there was a lack of pool development, lack of large woody debris, and degraded riparian condition. Management activities in the watershed that may be affecting stream temperature include grazing, road construction in the floodplain, historic logging activities, fuel wood removal, and recreational activities including dispersed camping, camping in developed sites, fishing, and ATV use (USDA Forest Service 2003(b), USDA Forest Service 2005(b)).

**Table 8.** Summary of data collected in Pecos Headwaters Watershed.

| River | Year Monitored | River Miles Monitored | # of thermo-graphs | NMED | | | SFNF Standards | | | Districts |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | NF | AR | PF | NF | AR | PF | |
| Pecos River | 2002 | 15.0 | 4 | 0 | 2 | 2 | 0 | 3 | 1 | Pecos/LV RD |
| Panchuela Creek | 2003 | 6.4 | 3 | 0 | 0 | 3 | 0 | 0 | 3 | Pecos/LV RD |
| Cave Creek | 2003 | 4.2 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | Pecos/LV RD |
| Horsethief Creek | 2003 | 4.6 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | Pecos/LV RD |
| Rito Perro | 2002 | 1.8 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | Pecos/LV RD |
| Rio Mora | 2002 | 17.7 | 3 | 0 | 0 | 3 | 0 | 3 | 0 | Pecos/LV RD |

(NF= not properly functioning, AR= at risk, PF= properly functioning)

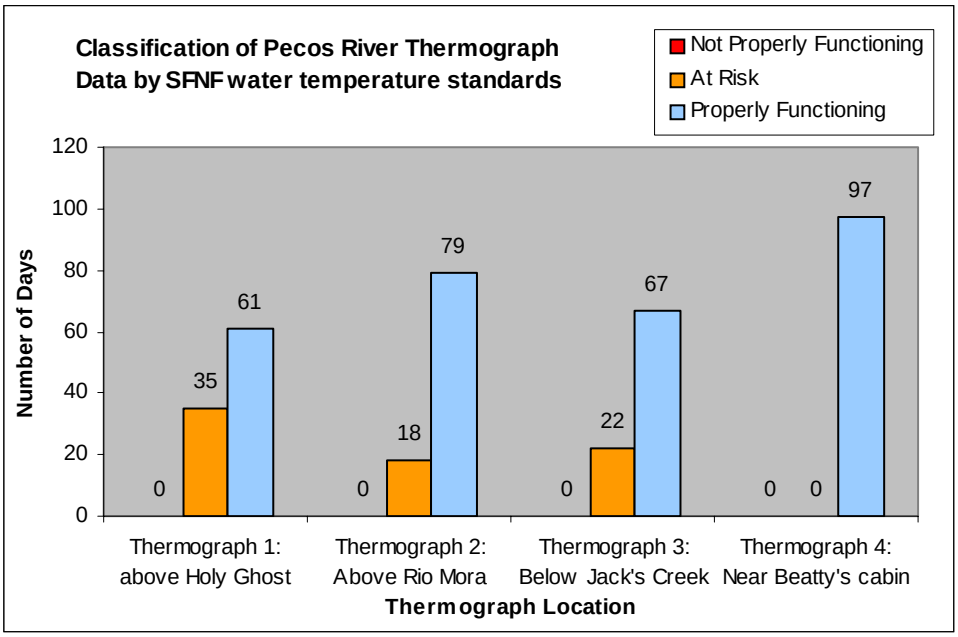
## *Pecos River*

Four temperature monitoring stations were established on the Pecos River (see map page 96). The stations were not moved for the duration of the survey. Water temperature was monitored from June 27th through October 29th, 2002. Thermographs recorded temperature at 15-minute intervals.

The first station was established at the beginning of the 2002 stream inventory, above the confluence with Holy Ghost (Reach 1, Wild and Scenic River* Mile 0.0). The next station was placed just above the confluence with Rio Mora (Reach 6, RM 2.75). The third station was located just below the confluence with Jack's Creek (Reach 8, RM 5.75). The uppermost thermograph station was placed near Beatty's Cabin, just above Forest Service Trail #260 bridge (Reach 12, RM 15.0).

Thermograph data collected between June 27th and September 30th, 2002 was used to determine water quality. When SFNF standards are applied three of the four stations are **at risk** (see Figure 94). All of these sites (above Holy Ghost, Above Rio Mora, and Below Jack's Creek) had more properly functioning days than at risk days. There were no not properly functioning days recorded.

**Figure 94**. Comparison of days not properly functioning, at risk, and properly functioning days at four thermograph locations on the Pecos River between June 26th and September 30th, 2002. Water temperature categories defined by SFNF water quality temperature standards are based on seven-day average maximum.




Two stations recorded **at risk** days when classified by NMED standards: Above Holy Ghost and Below Jack's Creek (see Figure 95). The number of days at risk for these two stations were much lower than the number of days properly functioning.

* The Pecos River flows over 296 miles from its mountain headwaters in the Pecos Wilderness to Rio Grande in Texas. The section of river designated as Wild and Scenic starts at the confluence with Holy Ghost and continues through the headwaters.

**Figure 95**. Comparison of days not properly functioning, at risk, and properly functioning days at four thermograph locations on the Pecos River between June 26th and September 30th, 2002. Water temperature categories defined by NMED water quality temperature standards are based on three-day average maximum.

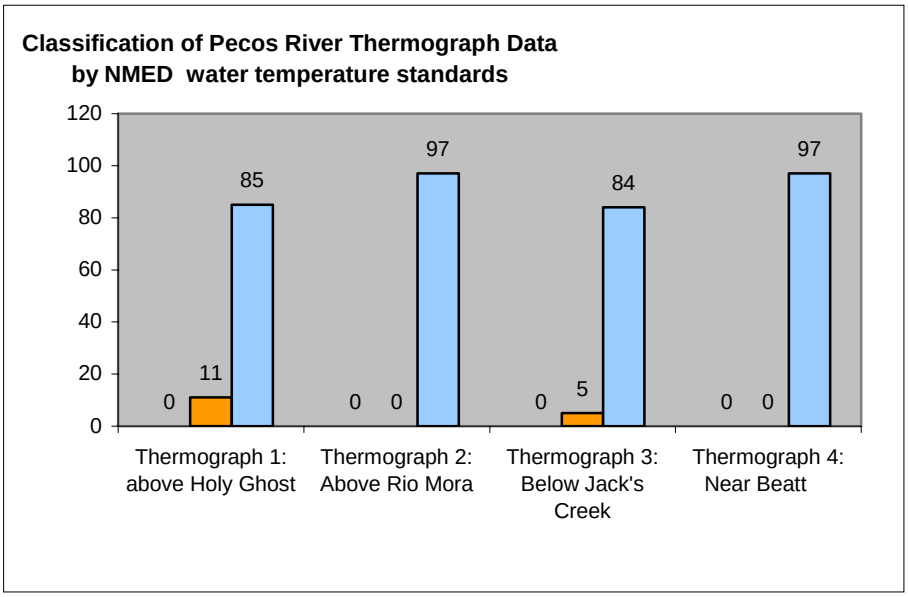
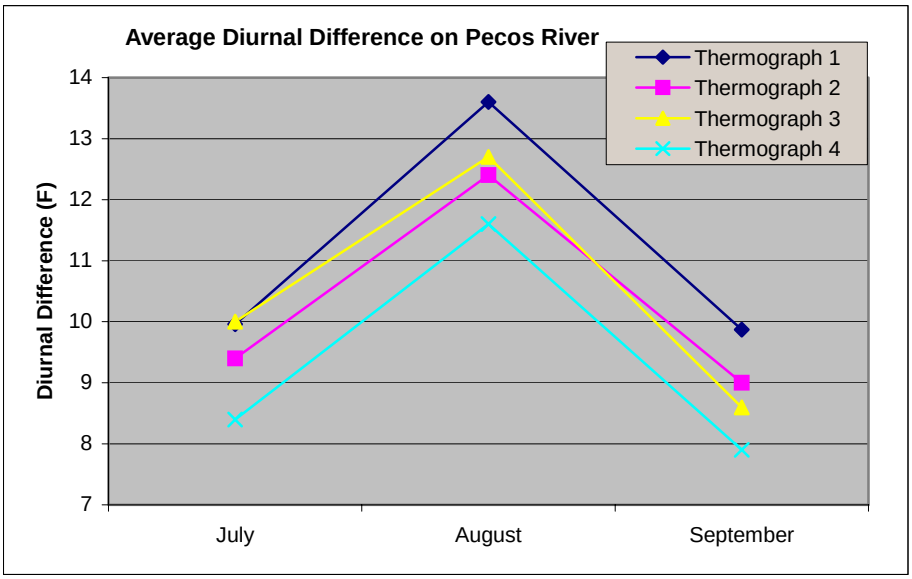


**Figure 97**. Diurnal difference averaged by month for four thermograph stations on Pecos River.




The **at risk** classification of multiple sites by both SFNF and NMED water quality standards implies that water temperature should be a management consideration for the Pecos River. Temperature mitigation strategies should be applied to protect the integrity of the coldwater fishery.

A stream inventory conducted in 2002 identified factors impacting the temperature of the Pecos River. One key factor is the degraded riparian vegetation along the river. Land use practices including, but not limited to, dispersed recreation have caused significant impacts on the riparian zone. Bank instability in high use areas was also identified as a factor impacting temperature on the Pecos. Bank instability leads to stream widening and increased sedimentation in the stream that can make the stream shallower (USDA Forest Service 2003(b)).

The most rapid temperature increase is between the Mora River (River Mile 2.75) and Holy Ghost (RM 0). This area receives high recreational use from campers and anglers at state-owned recreation areas. Three recreation areas are located in this area: Bert Clancy Campground, Rio Mora Campground, and Willow Creek Day Use Area. These recreational areas receive very high visitation during summer months and are not managed or maintained. The river is degraded near the recreational areas in a variety of ways that affect stream temperatures (see Photo 28). Observed stream degradation include trampled riparian vegetation, wood removed for campfires which are placed as close as 10 feet from the river, decreased bank stability, and other effects of an unmanaged recreation area. Another factor that could be influencing stream temperature between Mora confluence and Holy Ghost Creek is the stretch of private land and on-going Terrero Mine clean up efforts. The Superfund cleanup site leaves a large area of exposed fill material on a steep slope next to the Pecos River and Willow Creek (a tributary to the Pecos). During rain events, exposed soil runs around plastic barriers and into the Pecos River. The increased sediment load could be contributing to a temperature increase by causing stream shallowing (USDA Forest Service 2003(b)).

Surveyors recommended riparian planting to improve streambank conditions and provide thermal regulation. The plant roots will help hold the stream banks together and the limbs and leaves will provide shade to the creek. Human impacts could be limited by reducing the number of dispersed trails and campsites within the riparian zone (USDA Forest Service 2003(b)).

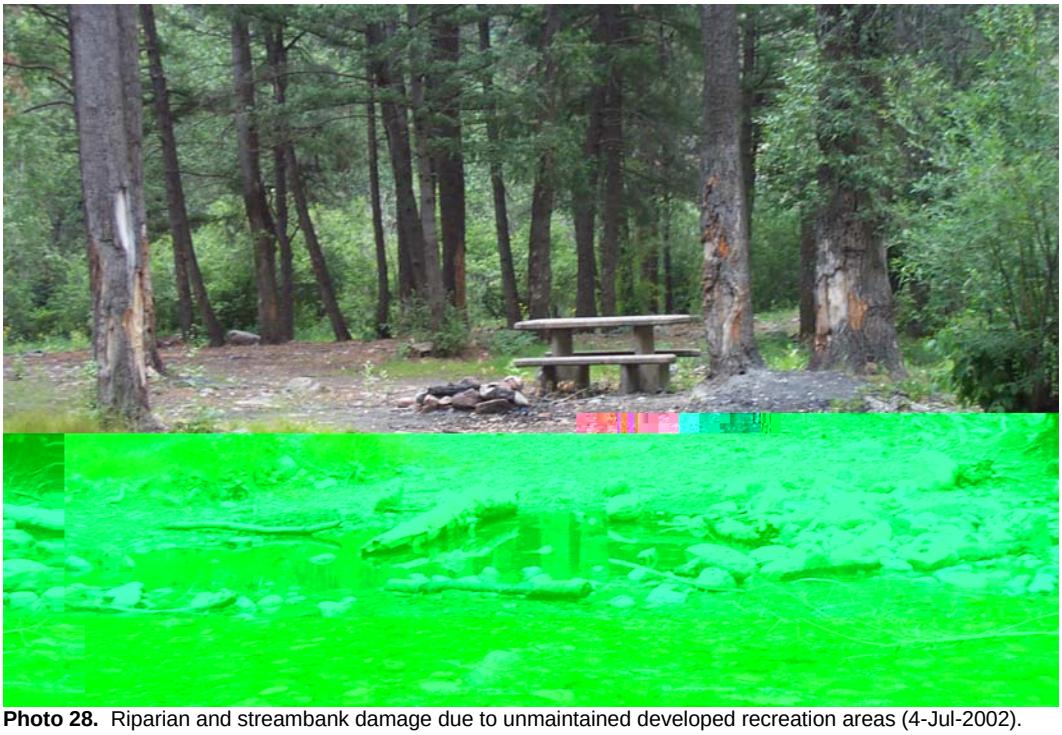


**Photo 28.** Riparian and streambank damage due to unmaintained developed recreation areas (4-Jul-2002).

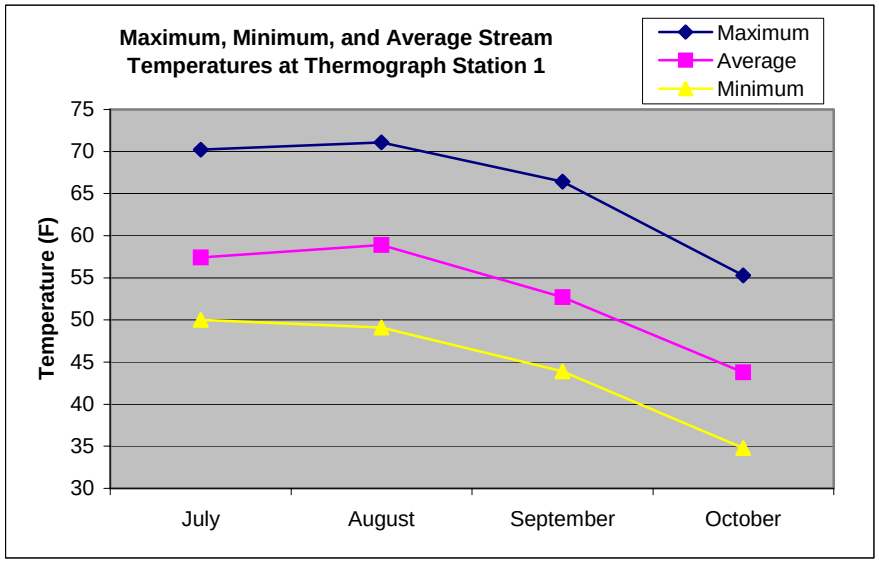
*Thermograph Station 1*: above Holy Ghost
*Elevation*: 7660'
*Stream Mile*: 0.0

Thermograph Station 1 monitored 2.9 stream miles. This section of Pecos River is managed primarily by State of New Mexico and private landowners. This stretch sees heavy recreational use. Highway 63 parallels this section of stream. Thermograph data collected in 2002 determined the Pecos River above the confluence with Holy Ghost was **at risk**, exceeding NMED standards 11 days out of 94 (11.7% of days). The site was **at risk** 35 days out of 90 (38.9% of days) by SFNF standards.

**Photo 29**. D. Goodman placing Thermograph 1 along left bank (26-Jun-03).

Maximum stream temperatures were recorded in August (see Figure 98). Stream temperature peaked at 71.1°F on August 18th. After August, temperatures decreased steadily until the thermograph was pulled in October.

**Figure 98.** Maximum, minimum, and average temperatures for each month at the thermograph station above the confluence with Holy Ghost.



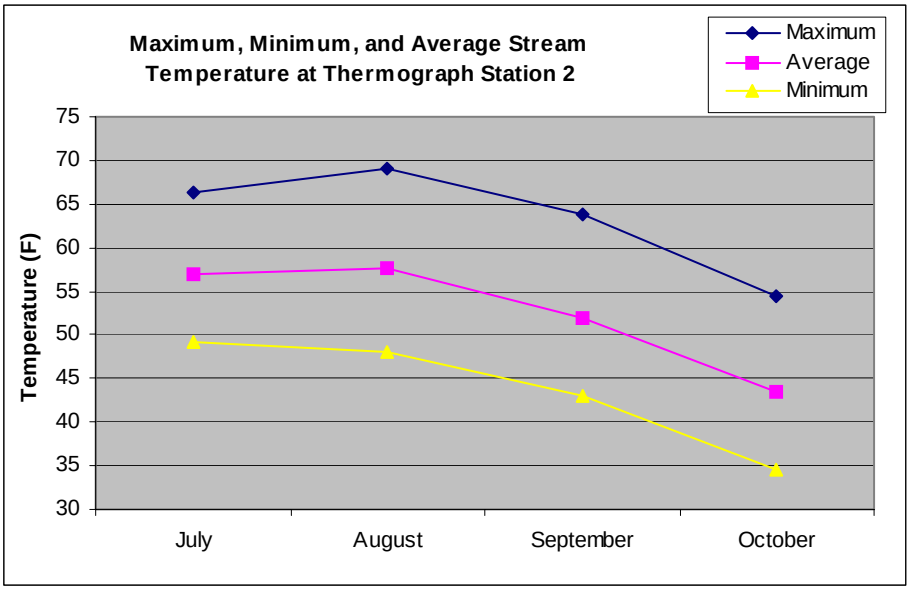

Diurnal difference was calculated for July through September. Average monthly diurnal difference peaked in July (see Figure 97). The maximum daily diurnal difference of 18.1°F was recorded on August 25th. The minimum daily diurnal difference of 2.8°F occurred on September 10th.

*Thermograph Station 2*: above Mora
*Elevation*: 7860'
*Stream Mile*: 2.9

Thermograph Station 2 monitored 3.6 stream miles. This section of Pecos River passes through an area of high recreational use. Highway 63 parallels the river for the entire length. Several developed recreational sites are found along the river. Thermograph data collected in 2002 determined the Pecos River above the confluence with Rio Mora was **at risk** by SFNF standards 18 days out of 91 (19.8% of days). The site was **properly functioning** by NMED standards.

**Photo 30**. D. Goodman pointing to Thermograph 2 with Rio Mora confluence in background left (26-Jun-03).

**Figure 99**. Maximum, minimum, and average temperatures for each month for the thermograph above the confluence with Rio Mora.




Diurnal difference was calculated for July through September. On average the month of August had the greatest diurnal differences (see Figure 97). The maximum daily diurnal difference of 15.6°F was recorded on August 10th. The minimum daily diurnal difference of 2.5°F occurred on September 10th.

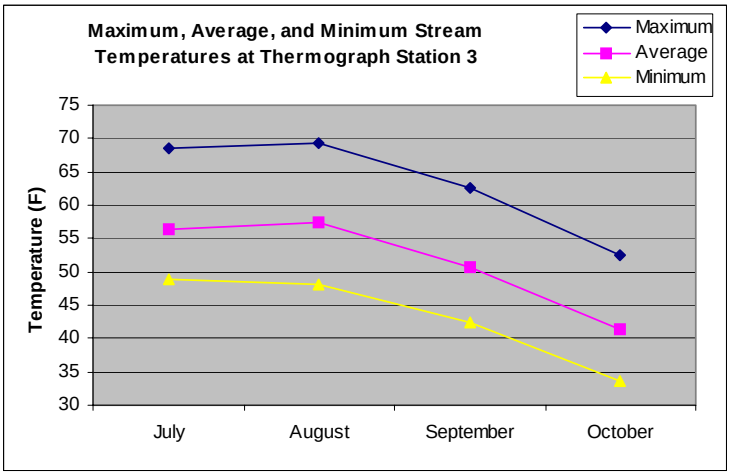
*Thermograph Station 3*: below Jack's Creek
*Elevation*: 8220'
*Stream Mile*: 6.4

Thermograph Station 3 monitored 7 stream miles. This section of Pecos River passes through a series of short open meadows and long tight canyons. It is primarily in the Pecos Wilderness. Thermograph data collected in 2002 determined the Pecos River below the confluence with Jack's creek was **at risk** by both NMED and SFNF water quality standards. By NMED standards, 5 days out of 87 (5.7% of days) were **at risk**. Twenty-two (22) days out of out of 83 (26.5% of days) were **at risk** by SFNF standards.

**Photo 31**. S. Ferrell standing where Thermograph 3 was deployed (04-Jul-03).

Maximum stream temperatures were recorded in August (see Figure 100). Temperature peaked at 69.4°F on August 4th. Temperatures decreased steadily though September and October until the thermograph was pulled.

**Figure 100.** Maximum, minimum, and average temperatures for each month at the thermograph station below the confluence with Jack's Creek.



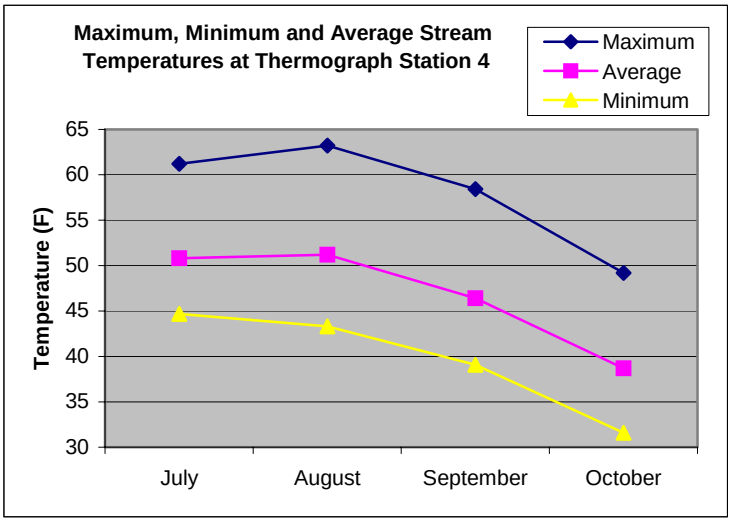

Diurnal difference was calculated for the months of July though September. August had on average the highest diurnal differences (see Figure 97). Daily diurnal difference peaked at 17.6°F on August 15th. The minimum daily diurnal difference of 2.2°F was recorded on September 10th.

*Thermograph Station 4*: near Beatty's cabin
*Elevation*: 9400'
*Stream Mile*: 13.6

Thermograph Station 4 monitored 6.9 stream miles. This section of Pecos River is located entirely in the Pecos Wilderness. It flows through a wide, low gradient river canyon at the bottom then steepens as it reaches its terminus. Thermograph data collected in 2002 determined the Pecos River near Beatty's cabin was **properly functioning** by both SFNF and NMED standards all 91 and 95 days respectively.

**Photo 32**. D. Goodman pointing to where Thermograph 4 was deployed (26-Jun-04).

**Figure 101**. Maximum, minimum, and average temperatures for each month at the thermograph station near Beatty's cabin.




Maximum stream temperatures were recorded in August (see Figure 101). Temperatures peaked at 63.2°F on August 4th. Temperatures decreased steadily through September and October until the thermograph was pulled.

Diurnal difference was calculated for the months of July though September. August had on average the highest diurnal differences (see Figure 97). Daily diurnal difference peaked at 15.4°F on August 25th. The minimum daily diurnal difference of 2.0°F was recorded on September 10th.

## *Panchuela Creek*

Three temperature monitoring stations were established on Panchuela Creek (see Figure 93). The stations were not moved for the duration of the survey. Water temperatures were recorded from June 20th to October 9th, 2003. Thermographs recorded temperature every 4 hours.

The first thermograph station was placed in Panchuela Creek across from the Forest Service-owned Panchuela Cabins below the wilderness boundary (RM 0.6). The second location was upstream of the confluence with Cave Creek (RM 2.3). The final station was located above the confluence with Rito Perro (RM 4.2).

Thermograph data collected between June 20th and September 30th was used to determine water quality in Pancheula Creek. When SFNF and NMED standards were applied all three sites were **properly functioning** (see Figures 102 and 103).

**Figure 102**. Comparison of days not properly functioning, at risk, and properly functioning at three thermograph sites in Panchuela Creek between June 20th and September 30th, 2003. Water temperature categories defined by SFNF water quality temperature standards are based on seven-day average maximum.

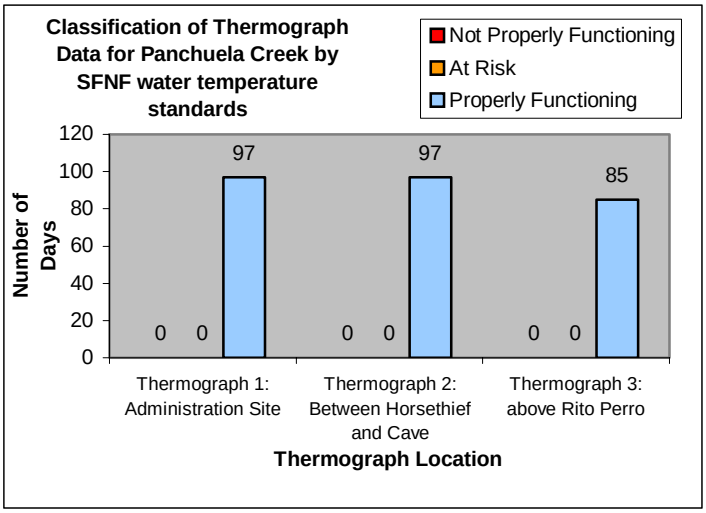
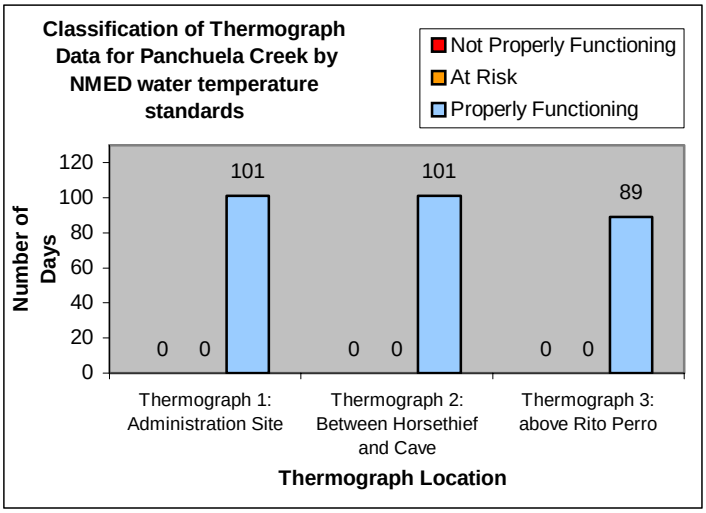



**Figure 103**. Comparison of days not properly functioning, at risk, and properly functioning at three thermograph sites in Panchuela Creek between June 20th and September 30th, 2003. Water temperature categories defined by NMED water quality temperature standards are based on three-day average maximum.

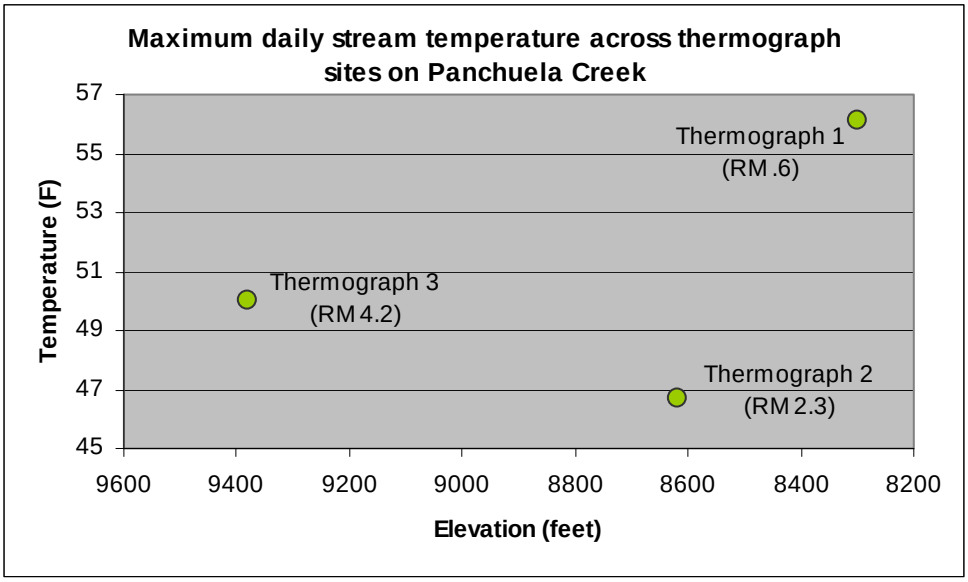



Looking at stream temperatures across elevation can also distinguish areas in need of temperature mitigation. On a typical system, temperatures should increases as elevation decreases. Panchuela Creek does not follow this pattern. On July 31st, the lowest daily maximum temperature (46.7°F) was recorded at Thermograph Station 2 (elevation 8620'). Thermograph Station 3 had the next lowest temperature of 50°F. Thermograph Station 1 had the highest maximum daily temperature of 62.8°F. This may be due in part to natural conditions (upwellings, coldwater springs, differing valley formations and aspect, etc.).

A station by station comparison of maximum temperatures on July 31st, 2003, revealed a 6.1°F increase in temperature from the most upstream station (above Rito Perro) to the station furthest downstream, Panchuela Administration Site (see Figure 104).

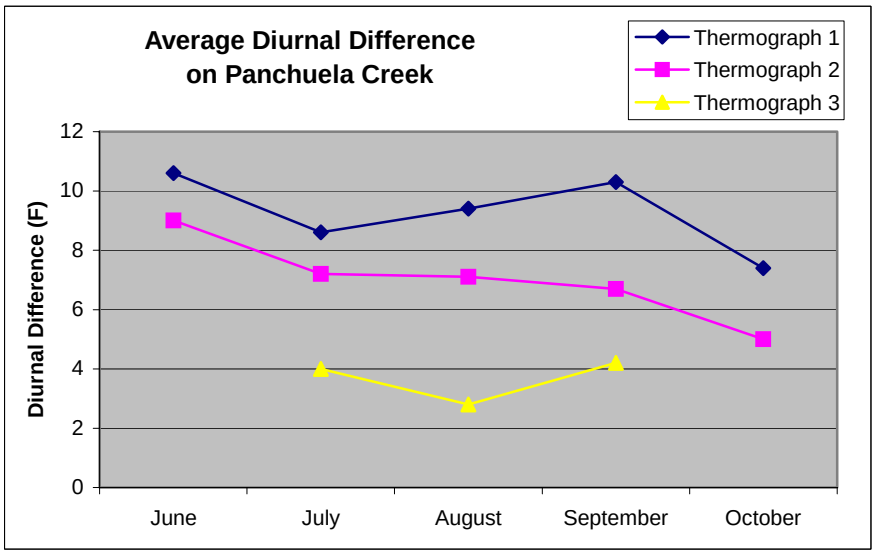
Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. On July 31st, 2003, diurnal fluctuations ranged from 4.7°F above Rito Perro to 7.6°F at the administration site. Diurnal difference data averaged by month showed a similar pattern. The station above Rito Perro consistently had the lowest diurnal difference and the administration site had the highest (see Figure 105).

**Figure 104**. Maximum stream temperatures on July 31st, 2003 across three thermograph stations on Panchuela Creek.




The **properly functioning** classification of multiple sites by both standards shows that Panchuela Creek can support a healthy cold-water fishery. This stream should be maintained in its current condition.

**Figure 105**. Diurnal difference averaged by month for the three thermograph stations on Panchuela Creek.




The profile of temperature over different elevations does not follow the typical pattern. In the case of Panchuela Creek, it is a characterization defined by geomorphology. Thermograph Station 2, rather than Station 3 which is at the higher elevation, recorded the lowest maximum temperature. This makes sense when the geomorphology of the stream canyon is examined. The section of stream above Thermograph Station 3 is more open with low rolling walls and frequent small grassy meadows naturally exposing the stream to increased solar radiation. The section of stream above Thermograph Station 2 is in a tighter canyon with tall steep walls. There is dense riparian cover and deep pools all of which contribute to thermal regulation (USDA Forest Service 2005(b)).

A stream inventory of Panchuela Creek was conducted in the summer of 2004. Surveyors found the streams to be in fairly pristine conditions. The primary impacts on the stream appeared to be from human recreation (stream widenings at trail crossings, brown out areas from campsites, some bank instability, etc). Compared to most systems though, these impacts were fairly minor. Recommendations for localized improvements can be found in the Panchuela Watershed Stream Inventory Report (USDA Forest Service 2005(b)).

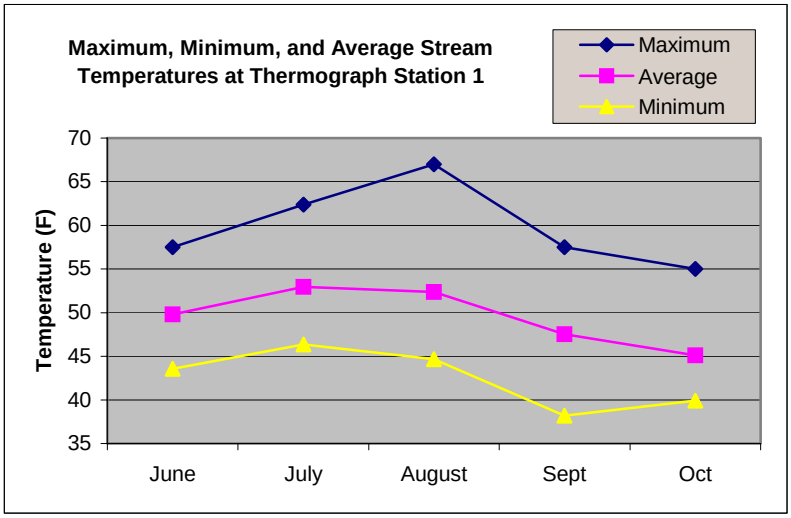
*Thermograph Station 1*: Administration Site
*Elevation*: 8300'
*Stream Mile*: 0.6

Thermograph Station 1 monitored 1.8 miles of stream. This section of creek begins below the wilderness boundary and passes through a fairly open canyon and some wide meadow sections. It ends just above the entrance of Cave Creek. Thermograph data collected in 2003 determined Panchuela Creek at the administration site (Panchuela Cabins) was **properly functioning** by both standards.

**Photo 33**. G. Sausen point to Thermograph 1 deployment site below the administration site (20-Jun-03).

Maximum stream temperatures were recorded in August (see Figure 106). Temperature in Panchuela Creek peaked at 67.0°F on August 4th. Temperatures then decreased steadily until the thermograph was pulled in October.

**Figure 106**. Maximum, minimum, and average temperatures for each month at the Administration site thermograph station.



Diurnal difference was calculated for June through October (see Figure 105). Average monthly diurnal difference peaked in June at 10.6°F and again in September at 10.3°F. Daily diurnal difference reached a maximum of 18.3°F on August 18th. The minimum recorded diurnal difference of 1.7°F occurred on August 29th.

*Thermograph Station 2*: Above Cave Creek
*Elevation*: 8620'
*Stream Mile*: 2.3

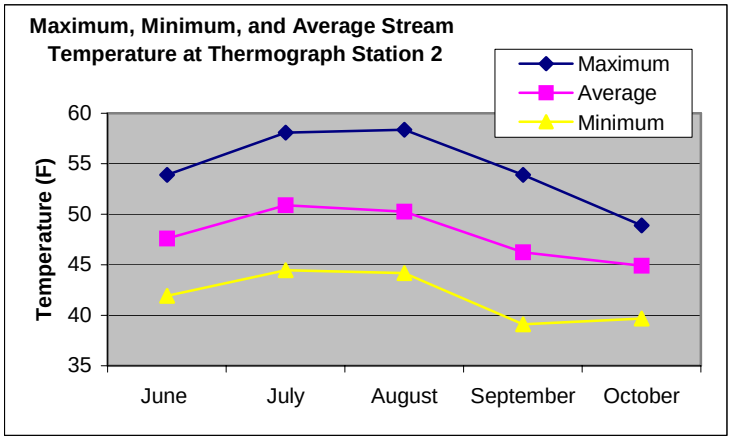
Thermograph Station 2 monitored 1.9 miles of stream. This section of stream flows through an open canyon for its entire length. Horsethief Creek confluence is approximately half way through this section. Thermograph data collected in 2003 determined Pancheula Creek above the confluence with Cave Creek was **properly functioning** by both standards.

Maximum stream temperatures were recorded in August, although August and July temperatures were very similar (see Figure 107). Temperature peaked at 58.4°F on August 8th. Temperatures decreased steadily until the thermograph was pulled in early October.

Diurnal difference was calculated for June through October. Average monthly diurnal difference peaked in June at 9°F (see Figure 105). The maximum daily diurnal difference of 11.4°F occurred on July 2nd. The minimum daily temperature fluctuation occurred of 1.7°F was recorded on August 20th.

**Photo 34.** S. Eddy deploying Thermograph 2 (20 Jun-03).

**Figure 107**. Maximum, minimum and average temperatures for each month above the confluence with Cave Creek.



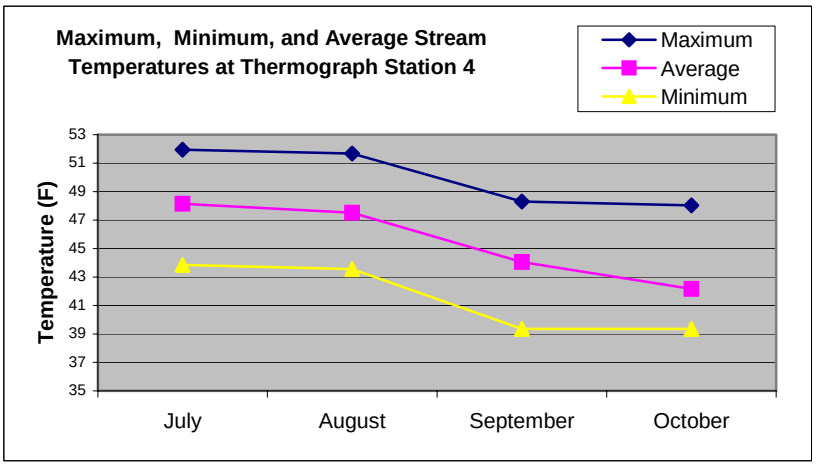
*Thermograph Station 3*: Above Rito Perro
*Elevation*: 9380'
*Stream Mile*: 4.2

Thermograph Station 3 monitored 2.7 miles of stream. This section of creek flows through a tight canyon above which it opens into a periodic meadow system with low rolling canyon walls. Thermograph data collected in 2003 determined Panchuela Creek above the confluence with Rito Perro was **properly functioning** by both standards.

**Photo 35**. S. Ferrell pointing to Thermograph 3 (01-Jul-04).

Maximum stream temperatures were recorded in July (see Figure 108). Temperature peaked at 52°F on July 18th. Stream temperatures then dropped in September and early October when the thermograph was pulled.

**Figure 108.** Maximum, minimum and average temperatures for each month for the thermograph station above Rito Perro.




Diurnal difference was calculated for July through September. Average monthly diurnal difference peaked in June at 4.2°F (see Figure 105). The maximum daily diurnal difference of 6.4°F occurred on July 2nd. The minimum daily diurnal difference of 1.1°F was recorded on August 29th.

## *Cave Creek*

One temperature monitoring station was established at the mouth of Cave Creek (elev. 8620', see Figure 93). The thermograph was not moved for the duration of the survey. This station monitored the 4.2 mile length of the creek. Water temperature was recorded between June 20th and October 8th, 2003. The thermograph recorded temperatures every 4 hours.

**Photo 36**. S. Eddy pointing to Cave Creek thermograph (20-Jun-03).

Thermograph data collected between June 20th and September 30th was used to determine water quality. When both SFNF and NMED standards were applied Cave Creek was **properly functioning** (see Figures 109 and 110).

**Figure 109**. Comparison of days not properly functioning, at risk, and properly functioning at the mouth of Cave Creek between June 20th and September 30th, 2003. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on seven-day average maximum.

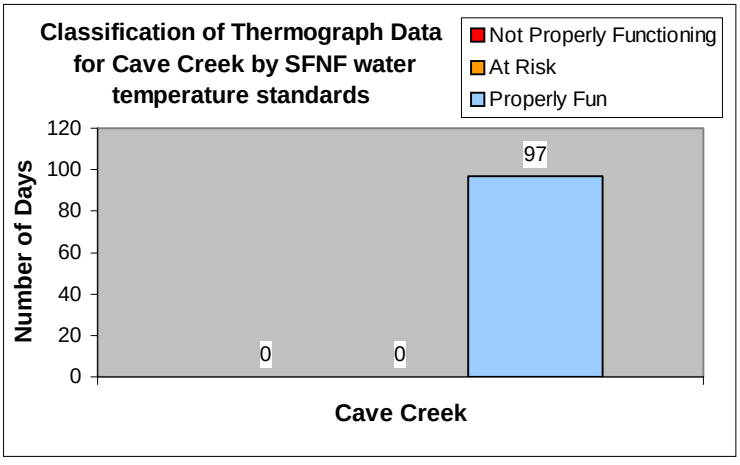
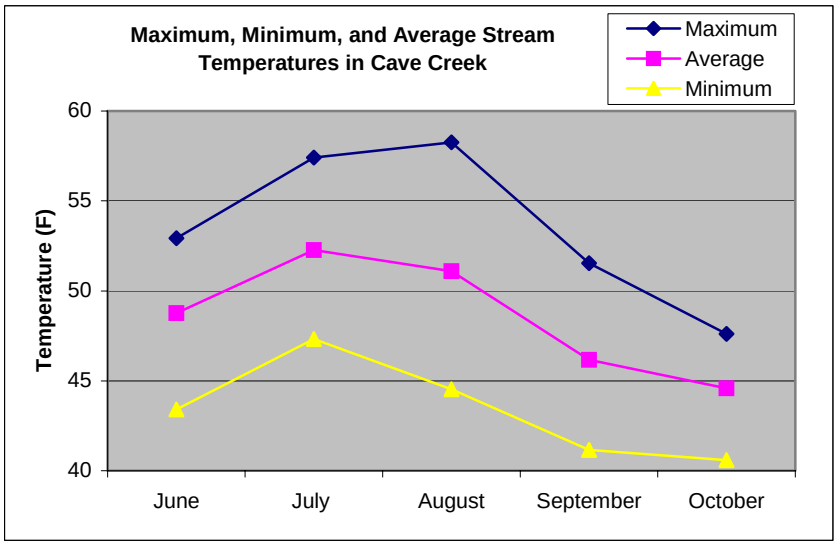


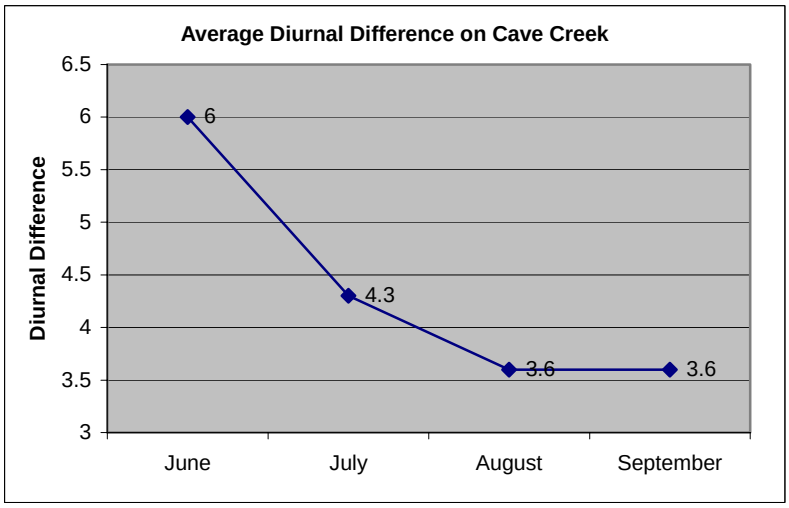

**Figure 110**. Comparison of days not properly functioning, at risk, and properly functioning at the mouth of Cave Creek between June 20th and September 30th, 2003. Water temperature categories defined by NMED Water Quality Temperature Standards are based on three-day average maximum.

**Figure 111**. Maximum, minimum, and average temperatures for each month for the thermograph station at the mouth of Cave Creek.




Average monthly diurnal difference peaked in June (see Figure 112). Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. The maximum daily diurnal difference of 7.3°F was recorded on June 23rd. The minimum daily temperature fluctuation of 0.8°F occurred on August 29th.

**Figure 112**. Diurnal difference averaged by month for the thermograph station on Cave Creek.




The **properly functioning** classification by both standards suggests this stream can support a healthy coldwater fishery. This system should be maintained in its current state.

A stream inventory of Cave Creek was conducted in the summer of 2004. Surveyors found the streams to be in fairly pristine conditions. The primary impacts on the stream appeared to be from human recreation (stream widenings at trail crossings, brown out areas from campsites, some bank instability, etc). Compared to most systems though, these impacts were fairly minor. Recommendations for localized improvements can be found in the Panchuela Watershed Stream Inventory Report (USDA Forest Service 2005(b)).

## *Horsethief Creek*

One temperature monitoring station was established at the mouth of Horsethief Creek (elev. 9020', see Figure 93). The station was not moved for the duration of the monitoring period. This station monitored the 4.6 mile length of the creek. Stream temperatures were measured from July 1st through October 9th, 2003. The thermograph recorded temperature every 4 hours.

**Photo 37**. S. Ferrell pointing to Horsethief Creek thermograph (01-Jul-04).

Thermograph data collected between July 1st and September 30th was used to determine water quality. When both SFNF and NMED standards are applied Horsethief Creek is **properly functioning** (see Figure 113 and 114).

**Figure 113**. Comparison of days not properly functioning, at risk, and properly functioning at the mouth of Horsethief Creek between July 1st and September 30th, 2003. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on seven-day average maximum.

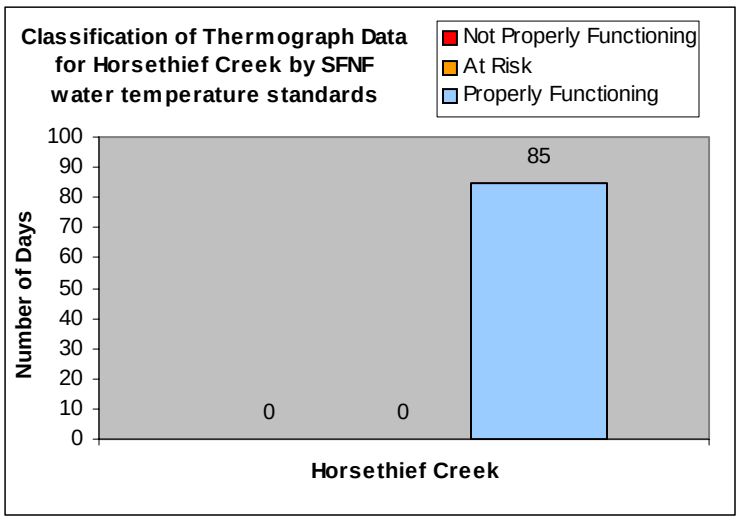
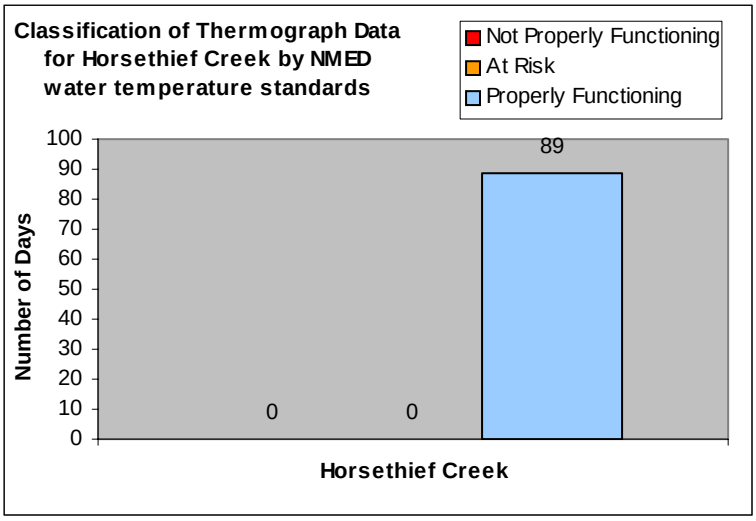
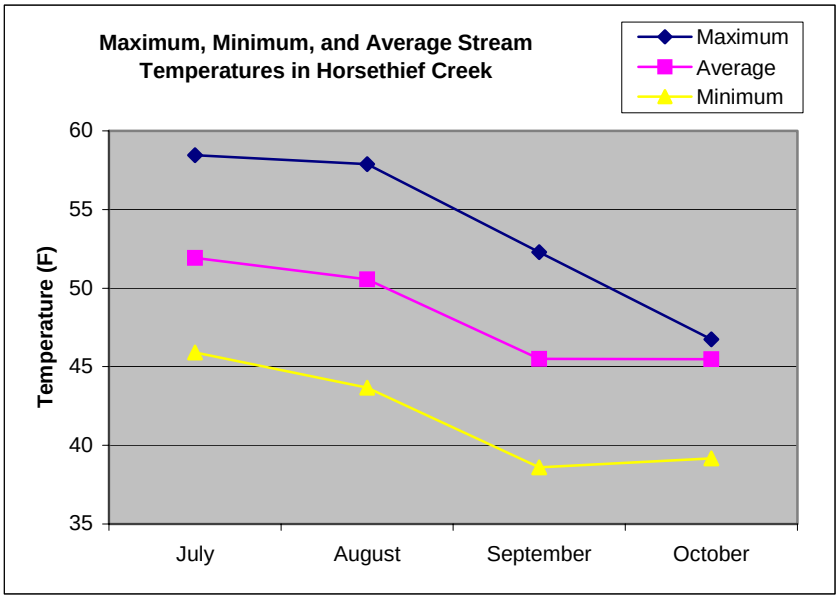



**Figure 114**. Comparison of days not properly functioning, at risk, and properly functioning at the mouth of Horsethief Creek between July 1st and September 30th, 2003. Water temperature categories defined by NMED Water Quality Temperature Standards are based on three-day average maximum.



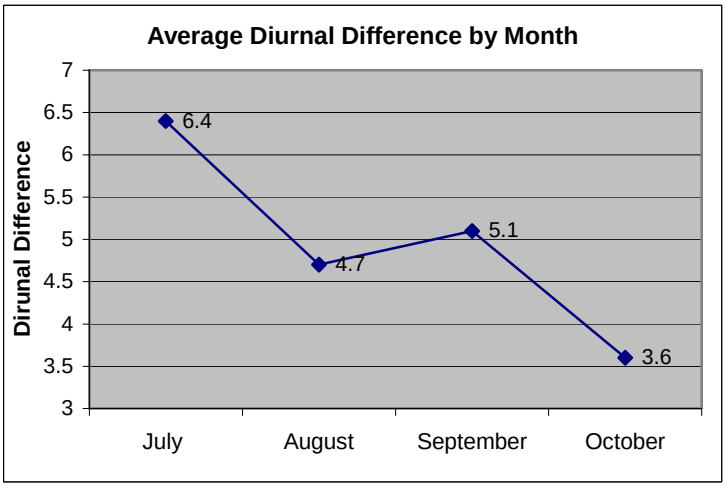

Maximum stream temperatures in Horsethief Creek were recorded in July (see Figure 115). Temperature peaked at 58.5°F on July 18th. After July, maximum temperatures decreased steadily until the thermograph was pulled in October.

**Figure 115**. Maximum, minimum and average temperatures for each month for the thermograph station at the mouth of Horsethief Creek.




Average monthly diurnal difference also peaked in July (see Figure 116). Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. The maximum daily diurnal difference of 10.6°F occurred on July 2nd. The minimum daily temperature fluctuation of 1.1°F was recorded on August 29th.

**Figure 116**. Diurnal difference averaged by month for the thermograph station on Horsethief Creek.




The **properly functioning** classification by both SFNF and NMED water quality standards suggests this stream can support a healthy coldwater fishery. This system should be maintained in its current state.

A stream inventory of Horsethief Creek was conducted in the summer of 2004. Surveyors found the streams to be in fairly pristine conditions. The primary impacts on the stream appeared to be from human recreation (stream widening at trail crossings, brown out areas from campsites, some bank instability, etc). Compared to most systems though, these impacts were fairly minor. Recommendations for localized improvements can be found in the Panchuela Watershed Stream Inventory Report (USDA Forest Service 2005(b)).

## *Rito Perro*

A water temperature monitoring station was established at the mouth of Rito Perro (elev. 9380', see Figure 93). The station was not moved for the duration of the monitoring period. This station monitored the entire 2.4 miles of stream. Stream temperature was monitored from July 1st through October 9th, 2003. The thermograph recorded temperature every four hours.

**Photo 38**. S. Ferrell pointing to Rito Perro thermograph (01-Jul-04).

Thermograph data collected between July 1st and September 30th was used to determine water quality. When both standards are applied Rito Perro was **properly functioning** (see Figure 117 and Figure 118).

**Figure 117**. Comparison of days not properly functioning, at risk, and properly functioning at the mouth of Horsethief Creek between July 1st and September 30th, 2003. Water temperature categories defined by SFNF Water Quality Temperature Standards are based on seven-day average maximum.

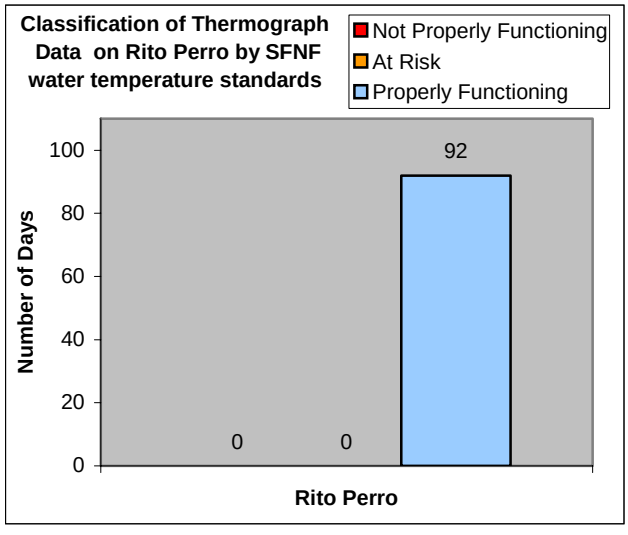
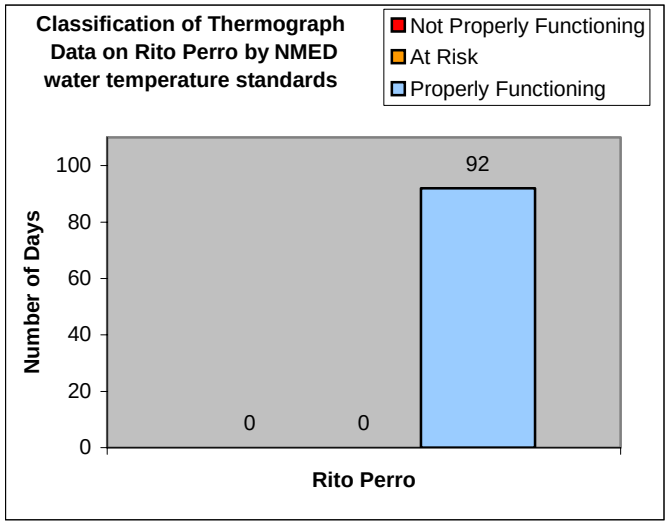
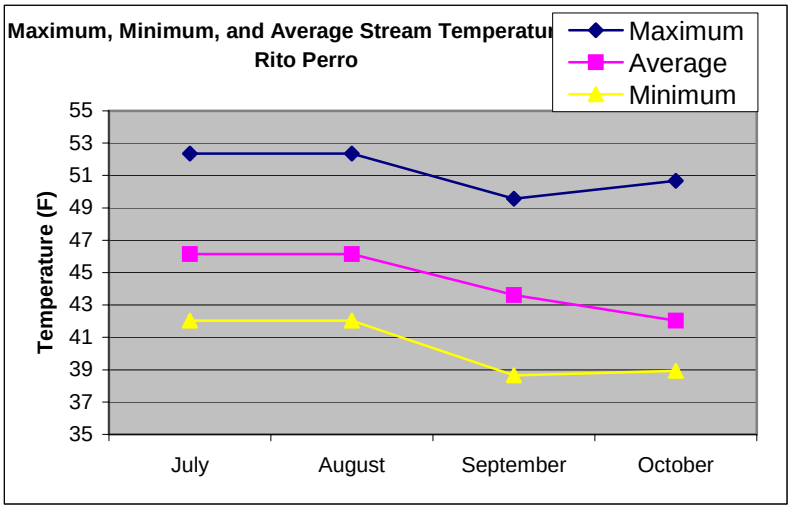



**Figure 118**. Comparison of days not properly functioning, at risk, and properly functioning at the mouth of Horsethief Creek between July 1st and September 30th, 2003. Water temperature categories defined by NMED Water Quality Temperature Standards are based on three-day average maximum.



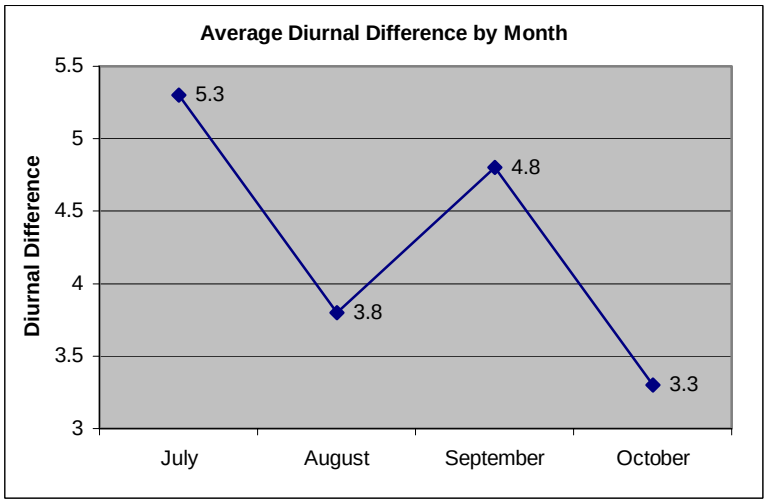

Maximum stream temperatures were recorded in July and August (see Figure 119). Stream temperatures peaked at 52.4°F on July 18th and August 4th. Maximum stream temperatures then decreased in September, but rose again in early October. The thermograph was pulled in early October.

**Figure 119**. Maximum, minimum, and average temperatures for each month for the thermograph station at the mouth of Rito Perro.




Average monthly diurnal difference peaked in July (see Figure 120). Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. The maximum daily diurnal difference of 8.4°F occurred on July 17th and 18th. The minimum daily diurnal difference of 1.4°F was recorded on August 29th.

**Figure 120**. Daily diurnal difference averaged by month.




The **properly functioning** classification by both standards suggests this stream can support a healthy coldwater fishery. This system should be maintained in its current state.

A stream inventory of Rito Perro was conducted in the summer of 2004. Surveyors found the streams to be in pristine conditions. The inaccessibility of this stream has severely limited human use. Recommendations for localized improvements can be found in the Panchuela Watershed Stream Inventory Report (USDA Forest Service 2005(b)).

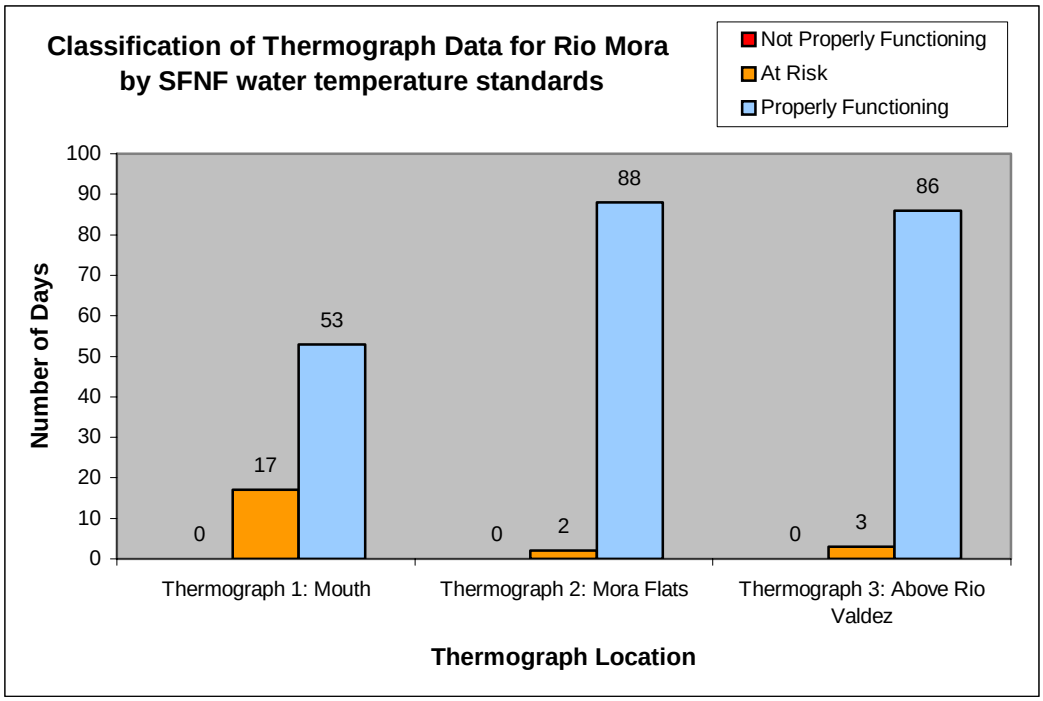
## *Rio Mora*

Three temperature monitoring stations were established in Rio Mora (see Figure 93). The stations were not moved for the duration of the monitoring period. Water temperature was monitored from June 25th through October 27th, 2002. Thermographs recorded stream temperature every 15 minutes.

The first station was placed at the mouth of Rio Mora (RM 0.3). The second was placed above in the Mora Flats area (RM 9.7). The final station was placed above the confluence with Rio Valdez (RM 9.8).

Thermograph data collected between June 25th and September 30th, 2002 was used to determine water quality. When SFNF standards are applied to this system, all three stations were **at risk** (see Figure 121). None of the sites had not properly functioning days and all the sites had significantly more properly functioning days than at risk days.

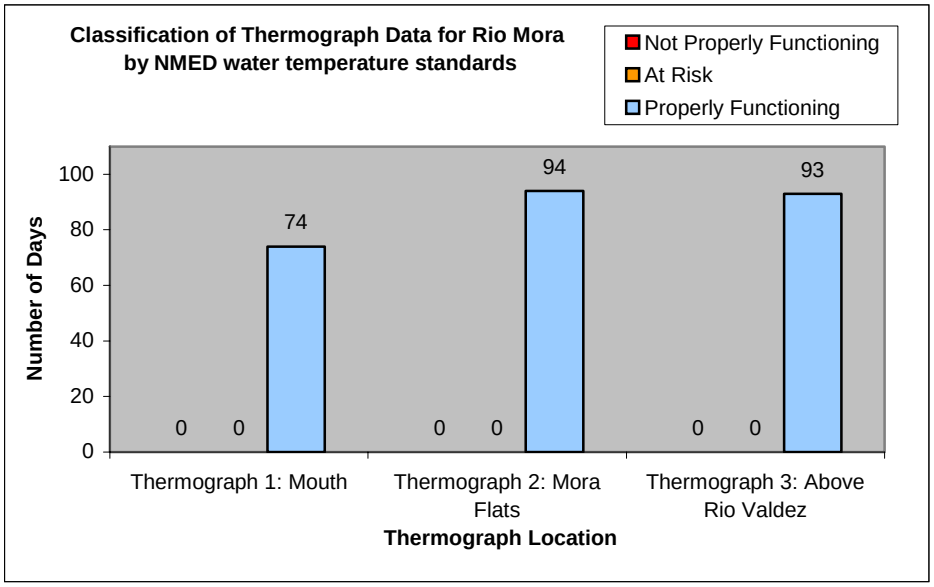
**Figure 121**. Comparison of days not properly functioning, at risk, and properly functioning at three thermograph sites in Rio Mora between June 25th and September 30th, 2002. Water temperature categories defined by SFNF water quality temperature standards are based on seven-day average maximum.




None of the three stations recorded at risk days when classified by NMED standards (see Figure 122). All three sites were **properly functioning**.

Looking at stream temperatures across elevation can also distinguish areas in need of temperature mitigation. On a typical system, temperatures should increase as elevation decreases. Rio Mora follows this pattern (see Figure 123). On July 31st, 2002 Thermograph Station 1 (elevation 7860') recorded the highest temperature of 58.6°F. Thermograph Station 3 (elevation 9280') exhibited the lowest maximum temperature of 57.9°F.

**Figure 122**. Comparison of days not properly functioning, at risk, and properly functioning at three thermograph sites in Rio Mora between June 25th and September 30th, 2002. Water temperature categories defined by NMED water quality temperature standards are based on three-day average maximum.




Diurnal difference is a measure of daily stream temperature fluctuation. It is determined by subtracting the minimum daily temperature from the maximum. The greater the diurnal difference the more stress fish experience adjusting to the changing temperatures. On July 31st, a diurnal difference of 11.1˚F was recorded above the confluence with Rio Valdez. At Mora Flats the diurnal difference was 10.9˚F. The mouth had the lowest diurnal difference of 8.1˚F. Thermograph Stations 1 and 2 exhibited similar diurnal differences over the course of the summer (see Figure 124). Thermograph Station 3 consistently had the lowest diurnal differences.

**Figure 123**. Maximum stream temperature on July 31st, 2002 across three thermograph stations on Rio Mora.

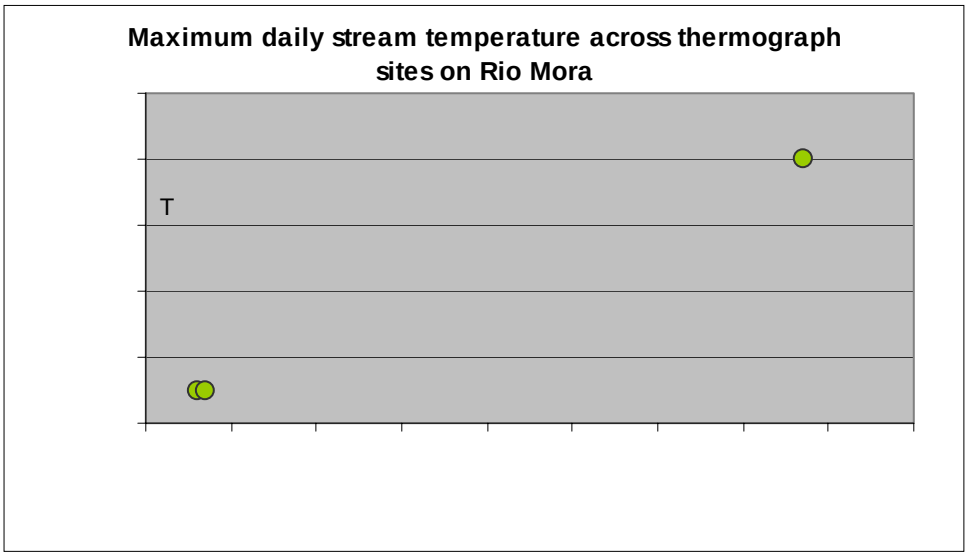
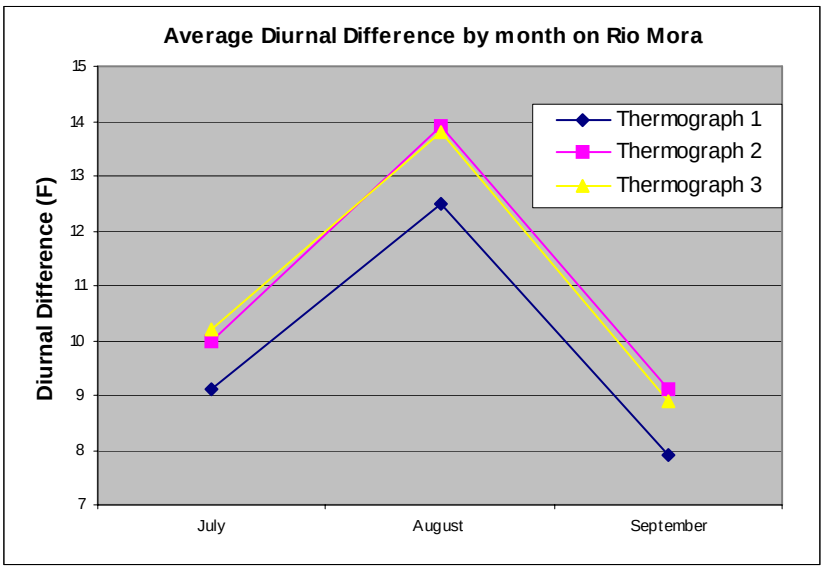


**Figure 124.** Diurnal difference averaged by month for three thermograph stations on Rio Mora.




The **at risk** classification of all three sites by SFNF water quality standards implies that water temperature should be a management consideration for Rio Mora. Temperature mitigating strategies should be applied to protect the integrity of the coldwater fishery. A stream inventory is scheduled for 2007 to help identify the conditions causing elevated temperatures in Rio Mora.

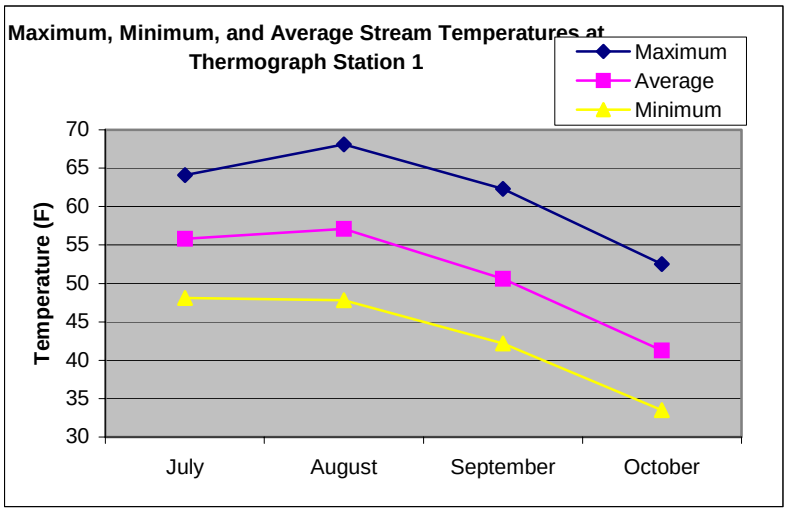
*Thermograph Station 1*: near Mouth
*Elevation*: 7860'
*Stream Mile*: .3

Thermograph Station 1 monitored 9.4 stream miles. This section of Rio Mora starts in Mora Campground, a state run campground, and moves into a tighter canyon. The upper portion of this section enters the Pecos Wilderness. Thermograph data collected in 2002 determined Rio Mora near its mouth was **at risk** by SFNF standards 17 days (24.3% of days) out of 70 recorded days. All 74 days were **properly functioning** by NMED standards.

**Photo 39**. S. Adams pointing to Thermograph 1 (16-Jul-03).

Maximum stream temperatures were recorded in August (see Figure 125). Temperature peaked at 68.1°F on August 4th, 2002. Temperatures then decreased steadily until the thermograph was pulled in October.

**Figure 125**. Maximum, minimum, and average temperatures for each month at the thermograph station at the mouth of Rio Mora.




Diurnal difference was calculated for the months of July though September. August had on average the highest diurnal differences (see Figure 124). Daily diurnal difference peaked at 17.2°F on August 25th. The minimum daily diurnal difference of 2.0°F was recorded on September 10th.

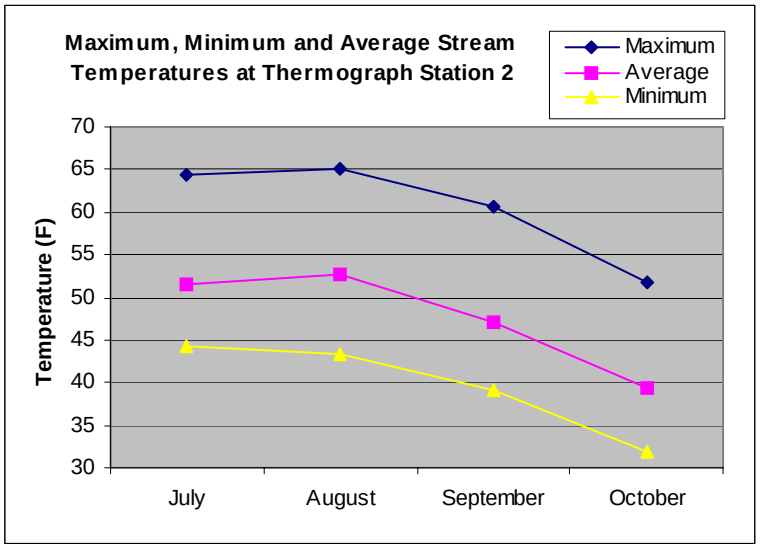
*Thermograph Station 2*: Mora Flats
*Elevation*: 9260'
*Stream Mile*: 9.7

Thermograph Station 2 monitored 0.2 stream miles. This section of Rio Mora is in an open meadow system just below the confluence with Rio Valdez. The short monitoring section was used to determine the influence Valdez has on Mora. Thermograph data collected in 2002 determined Rio Mora in Mora Flats was **at risk** 2 days out of 90 by SFNF standards (2.2% of days). The site was **properly functioning** all 94 days by NMED standards.

**Photo 40**. D. Goodman pointing to Thermograph 2 (26-Jul-04).

Maximum stream temperatures were recorded in August (see Figure 126). Temperature peaked at 65.1°F on August 11th. Temperature then decreased steadily through October when the thermograph was pulled.

**Figure 126**. Maximum, minimum, and average temperatures for each month at the thermograph station in Mora Flats.




Diurnal difference was calculated for the months of July though September. August had on average the highest diurnal differences (see Figure 125). Daily diurnal difference peaked at 19.0°F on August 25th. The minimum daily diurnal difference of 2.0°F was recorded on September 10th.

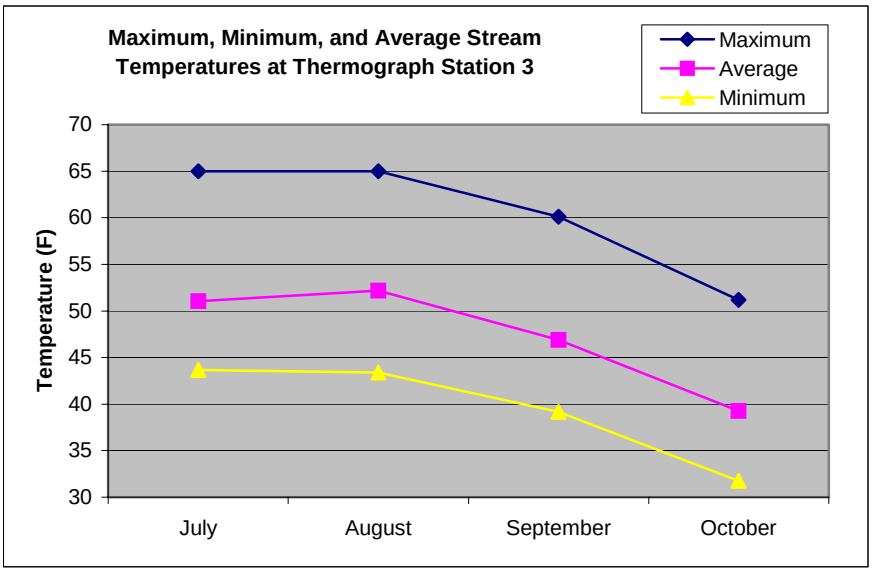
*Thermograph Station 3*: above Rio Valdez
*Elevation*: 9280'
*Stream Mile*: 8.1

Thermograph Station 3 monitored 8.1 miles of stream. This section of stream begins just above the confluence with Rio Valdez and flows to the headwaters. Thermograph data collected in 2002 determined Rio Mora above the confluence with Rio Valdez was **at risk** 3 days out of 89 total days (3.4% of the total days). The site was **properly functioning** all 93 days by NMED standards.

**Photo 41**. M. Boatright pointing to Thermograph 3 (26-Jun-04).

Maximum stream temperatures were recorded in July and August (see Figure 127). Temperature peaked at 65°F on July 9th and August 11th. Temperatures then decreased steadily until the thermograph was pulled in October.

**Figure 127.** Maximum, minimum, and average temperatures for each month at the thermograph station above the confluence with Rio Valdez.




Diurnal difference was calculated for the months of July though September. August had, on average, the highest diurnal differences (see Figure 125). Daily diurnal difference peaked at 19.9°F on July 17th. The minimum daily diurnal difference of 1.7°F was recorded on September 10th.

# Literature Cited

Dickerson, B.R., and G.L. Vineyard. 1999. Effects of high chronic temperatures and diel temperature cycles on the survival and growth of Lahontan cutthroat trout. Transactions of the American Fisheries Society. 128: 516-521.

Dunham, J. 1999. Stream temperature criteria for Oregon's Lahontan cutthroat trout Oncorhynchus clarki henshawi. Department of Biology and Biological Resources Research Center University of Nevada.

Hubert, W. A. and W. A. Gern. Influence of embryonic stage on survival of cutthroat trout exposed to temperature reduction. Prog. Fish-Culturist 57: 326-328.

Meeuwig, M.H., J. B, Dunham, J.P. Hayes, G.L. Vineyard. 2004. Effect of constant and cyclical thermal regimes on growth and feeding of juvenile cutthroat trout of variable sizes. Ecology of Freshwater Fish 13(3): 208-216.

New Mexico Environmental Department. 2000. State of New Mexico procedures for assessing standards attainment for 303(d) list and 305(b) report assessment protocol. October 2000. New Mexico Environment Department, Surface Water Quality Bureau. Santa Fe, New Mexico.

New Mexico Environment Department. 2003. Approved 2002-2004 State of New Mexico Section 303(d) List for Assessed River/Stream Reaches Requiring Total Maximum Daily Loads (TMDLs). June 2003. New Mexico Environment Department, Surface Water Quality Bureau. Santa Fe, New Mexico.

New Mexicon Environment Department. 2004. State of New Mexico procedures for assessing standards attainment for the integrated 303(d)/305(b) water quality monitoring and assessment report: assessment protocol. April 2004. New Mexico Environment Department, Surface Water Quality Bureau. Santa Fe, New Mexico.

Oregon Department of Environmental Quality. August 1997. The Scientific Basis for Oregon's Stream Temperature Standard: Common Questions and Straight Answers (authors: M. Boyd and D. Sturdevant). Portland, Oregon.

Smith, C.E., W.P. Dwyer and R.G. Piper. 1983. Effect of water temperature on egg quality of cutthroat trout. Progressive Fish Culturist 45: 176-178.

USDA Forest Service. 2002. East Fork Jemez River Stream Inventory Report (author: J. Simino). Santa Fe, New Mexico.

USDA Forest Service. 2003(a). Cow Creek Stream Inventory Report (author: C. Gatton). Santa Fe, New Mexico.

USDA Forest Service. 2003(b). Pecos River Stream Inventory Report (author: D. Goodman). Santa Fe, New Mexico.

USDA Forest Service. 2003(c). Respect the Rio Annual Report 2003: Dispersed Recreation Component. Santa Fe, New Mexico.

USDA Forest Service. 2003(d). Rio Cebolla Stream Inventory Report (author: J. Simino and M. Bassett). Santa Fe, New Mexico.

USDA Forest Service. 2003(e). San Antonio Creek Stream Inventory Report (author: D. Goodman). Santa Fe, New Mexico.

USDA Forest Service. 2004. Rio de las Vacas Stream Inventory Report (author: S. Eddy, D. Goodman, K. Lund and J. Simino). Santa Fe, New Mexico.

USDA Forest Service. 2005(a). Cañones Creek Stream Inventory Report (author: S. Eddy). Santa Fe, New Mexico

USDA Forest Service. 2005(b) *pending*. Panchuela Creek Watershed Stream Inventory Report. Santa Fe, New Mexico.

USDA Forest Service. 2005(c) *pending*. Polvadera Creek Stream Inventory Report (author: K. Krishna). Santa Fe, New Mexico.

USDA Forest Service. 2005(d) *pending*. Respect the Rio Annual Report 2004. Santa Fe, New Mexico.

USDA Forest Service. 2005(e) *pending.* Rio Guadalupe Stream Inventory Report (author: C. Dentino. Santa Fe, New Mexico.

US Environmental Protection Agency. 2003. EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards. EPA 910-B-03-002. Region 10 Office of Water, Seattle, WA.

Van Dorn, Carol. 2005. Personal communication with Forest Soils Scientist and Hydrologist, Santa Fe National Forest, March 2005.

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